

V. ATABEKOV

ELECTRIC POWER SYSTEM INSTALLATION PRACTICE

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В. Б. АТАБЕКОВ

МОНТАЖ ЭЛЕКТРИЧЕСКИХ СЕТЕЙ
И СИЛОВОГО
ЭЛЕКТРООБОРУДОВАНИЯ

ИЗДАТЕЛЬСТВО «ВЫСШАЯ ШКОЛА» МОСКВА

V. ATABEKOV

**Electric
Power System
Installation
Practice**

*Translated from the Russian
by O. VOLODINA*

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The Greek Alphabet

Α α	Alpha	Ι ι	Iota	Ρ ρ	Rho
Β β	Beta	Κ κ	Kappa	Σ σ	Sigma
Γ γ	Gamma	Λ λ	Lambda	Τ τ	Tau
Δ δ	Delta	Μ μ	Mu	Υ υ	Upsilon
Ε ε	Epsilon	Ν ν	Nu	Φ φ	Phi
Ζ ζ	Zeta	Ξ ξ	Xi	Χ χ	Chi
Η η	Eta	Ο ο	Omicron	Ψ ψ	Psi
Θ θ ϑ	Theta	Π π	Pi	Ω ω	Omega

The Russian Alphabet and Transliteration

А а	a	К к	k	Х х	kh
Б б	b	Л л	l	Ц ц	ts
В в	v	М м	m	Ч ч	ch
Г г	g	Н н	n	Ш ш	sh
Д д	d	О о	o	Щ щ	shch
Е е	e	П п	p	Ъ ъ	"
Ё ё	ye, e	Р р	r	Ы ы	y
Ж ж	zh	С с	s	Ь ь	'
З з	z	Т т	t	Э э	e
И и	i	У у	u	Ю ю	yu
Й й	y	Ф ф	f	Я я	ya

На английском языке

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Introduction

The main criterion of technical standards of any country is at present the state of development of its power engineering capacity of power plants, and production of electric energy.

The per-unit power output of turbogenerators and water-wheel generators is ever growing along with the length and rated voltage of high-voltage power transmission systems. Power transmission lines rated 800 kV are now in use, and planned for the erection in the near future are 1,000- and 1,500-kV lines.

High-power systems have been organized, in which as many as tens and hundreds of large power plants are interconnected and their operations coordinated with respect to power supply.

A high level of development of power engineering has made it possible to utilize electric energy in leading branches of industry, such as agriculture, construction, and transport.

Electric power sets in motion millions of machines and mechanisms, founds metals, galvanically plates metal surfaces with anticorrosion and antiacid coatings, paints miscellaneous parts in an electric field, automatically controls technological processes and intricate automatic-control lines of machines and conveyers.

The continuous growth of industry is connected with the construction of new factories or the expansion of old ones. A construction or reconstruction of any factory, dwelling house, school, hospital, theatre, etc. is apt to involve a great amount of electrical installation and wiring work.

Installation of electrical equipment on most modern factories includes a great number of complicated jobs, such as:

- installation and wiring of factory and shop distribution and transformer substations;

- installation of long cable and overhead power transmission lines rated at different voltages;

- installation and wiring of shop's metalclad switchgear and control boards;
- installation of hoisting and haulage equipment (elevators, hoists, overhead travelling cranes, electric telfers, etc.);

- installation of shop's industrial and lighting wiring systems;

- installation of ancillary equipment;

installation and wiring of automatic-control, regulation, and monitoring systems.

This intricate work can be done only by electricians who have acquired the necessary theoretical knowledge and practical skill in the job.

This Manual contains all necessary pieces of information on the theory and practice of the installation and wiring of electrical equipment of industrial plants, and also on the organization, industrialization, and planning of the work.

CHAPTER ONE

Electric Power Production, Distribution, and Utilization

1.1. Natural Power Sources and Characteristics of Electric Energy

The material wealth of any society is created nowadays by the common labour of its people. Any work involves the consumption of the respective amount of energy that can be of a different nature, such as muscular energy of human beings or animals, or natural energy.

The muscular energy of human beings and animals was the only source of energy in the bygone days of human society. A continuous growth and expansion of human spheres of activity required more energy that could be taken from natural sources.

The surrounding nature is rich in electric energy resources that differ by their origin and quality, and by methods of their utilization by men. Coal and petroleum deposits, water of rivers and seas, heat of the sun and earth's entrails, force of moving air streams are good resources of energy.

The most efficient utilization of natural resources has become possible with the advent of electricity because almost all the natural energy carriers are actually suitable for the production of electric power.

Electric energy is at present the most popular type of energy and its annual world's production amounts to several thousand billions of kilowatt-hours.

Such popularity of electric energy is attributed to its peculiar features that are not characteristic of any other types of energy known at present.

Electric energy can be:

transmitted over distances as long as hundreds and thousands of kilometres;
easily distributed to many power consumers;

converted to other types of energy, such as thermal or mechanical energy.

Electric energy is most advantageous from the economic point of view. Thermal-electric power plants, for example, use in most cases low-valued types of fuel, such as low-grade coal, peat, shales, etc.

Electric power is generated by power plants or stations which are classified according to the type of energy they use as thermal, nuclear, and hydraulic power plants. Power plants are also classified according to the prime movers as steam-turbine, hydroelectric, gas-turbine, and diesel-electric power plants.

Most large power plants are built nowadays with steam or hydraulic turbines as prime movers.

1.2. Electric Power Plants

1.2.1. Types of Electric Power Plants

An electric power plant is a plant that generates electric power by using energy carriers or by converting various types of energy.

Steam-turbine and hydroelectric power plants are now the chief sources of electric power, although an ever growing number of large nuclear power plants are put into service each year.

Steam-turbine power plants utilize coal, petroleum, natural gas burned in the furnaces of their boilers. The heat generated in the process converts water in the boilers into steam that sets in motion the turbine rotors. The mechanical energy of the turbine rotors is imparted to the rotors of generators wherein it is converted into electric energy.

Nuclear power plants depend for their operation on the same principle as steam-turbine plants, the only difference being that heat is generated in them due to the fission of radioactive elements or their isotopes.

Hydroelectric power plants use water to set in motion the turbine runner. Water power is derived from the force exerted by water in falling through a certain head created by the difference in the upstream and downstream water.

There are also wind-electric, helium-electric, geothermal, tidal, and other power plants utilizing, respectively, the energy of wind, heat of sun rays and earth's bosom, energy of sea and ocean tides.

1.2.2. Steam-Turbine Power Plants

About 80 per cent of electric power consumed in the USSR is generated by steam-turbine power plants. What makes them in favour in this country are their technical and economic advantages, such as:

- standardization of buildings and layout of equipment in them;
- construction of buildings and their components from factory-made elements;
- construction and erection of power plants within the shortest possible time with added advantage of minimum capital investment;
- use of power units of high per-unit capacity;
- provision for comissioning all the power units of the plant within minimum time.

The main parts of the steam-turbine power plants are as follows:

steam boiler wherein the chemical energy of combusted fuel is converted into the thermal energy of steam that is supplied to the turbine;

steam turbine that functions as a prime mover wherein the thermal energy of steam is transformed into mechanical energy;

electric generator that converts the mechanical energy into electric power.

According to the production process, the steam-turbine power plants are classified as condensing and heat-electric generating plants.

A condensing power plant is used for the production of electric energy only. Feed water for boilers, steam, and condensate circulate in the power plant over a closed circuit.

Figure 1 illustrates a condensing power plant operating on pulverized coal fuel. Lumps of raw coal are supplied by conveyers from a store 1 to a coal crusher 2 wherefrom crushed coal is delivered to the ball pulverizer of a pulverizing compartment 3. Pulverized coal is drawn out of the pulverizer by a drawing fan and is fed over a pulverized fuel line to a fuel hopper and then to nozzles provided in

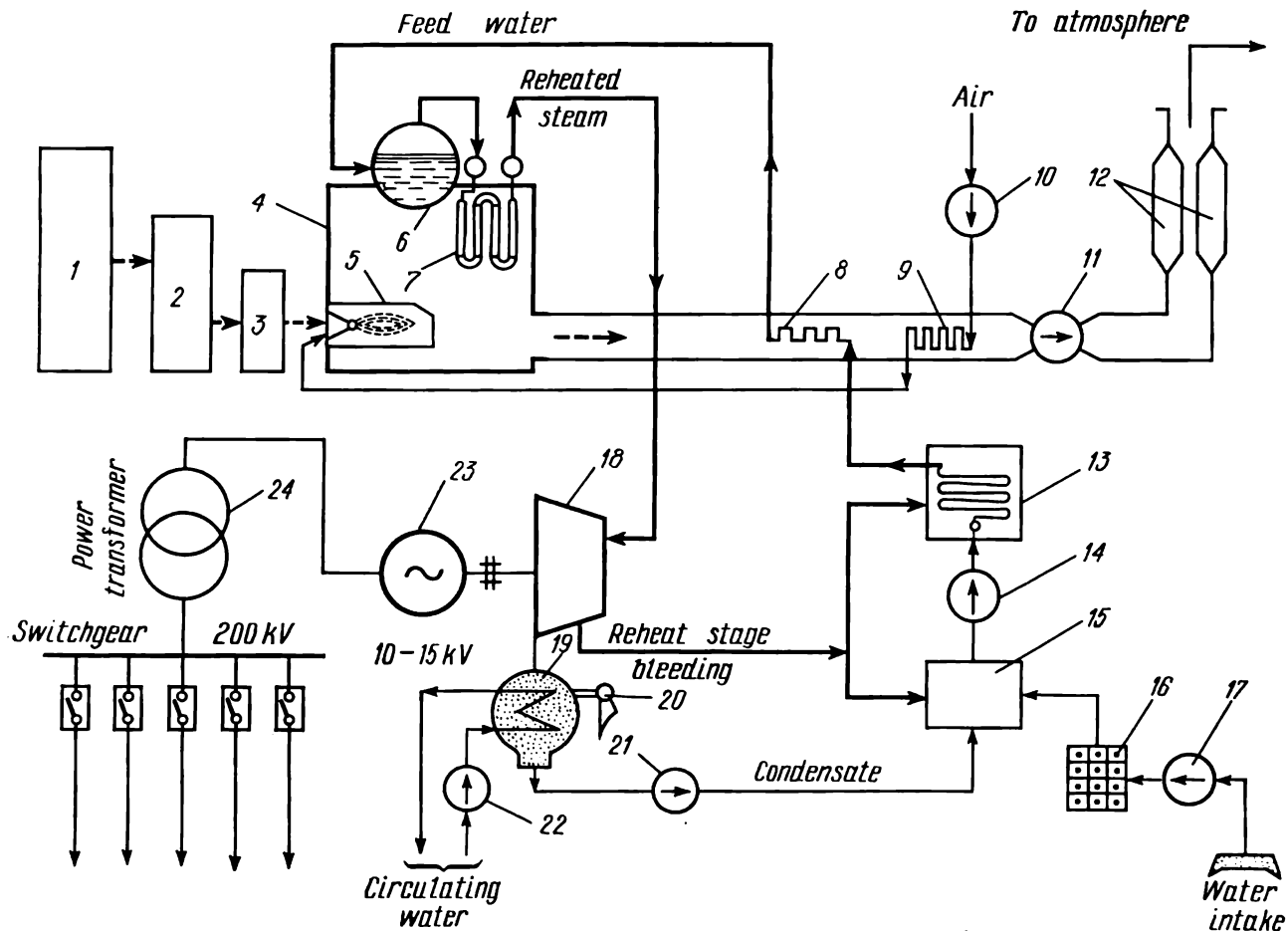


Fig. 1. Schematic diagram of a condensing steam-turbine power plant

1—coal store; 2—coal crusher; 3—pulverizing compartment; 4—boiler; 5—boiler furnace; 6—boiler drum; 7—steam reheat; 8—economizer; 9—air heater; 10—blast air fan; 11—draft fan; 12—electric filters; 13—water heater; 14, 17, 21, 22—pumps; 15—deaerator; 16—water-treatment plant; 18—steam turbine; 19—condenser; 20—ejector; 23—generator; 24—transformer

the furnace 5 of the boiler 4. On its way from the pulverizer to the nozzles, pulverized fuel is passed through a separator wherein large fragments of coal are separated and returned to the pulverizer. Then pulverized fuel is delivered to a cyclone to be separated from air.

Pulverized fuel is admitted to the furnace through nozzles at a definite pressure created by a blast air fan 10.

The air delivered by the blast air fan 10 to the nozzles and to the furnace (to maintain the combustion process) is heated in an air heater 9 arranged on the path of hot gases exhausted by a draft fan 11. This is necessary to prevent cooling of the

furnace and, in this way, to save heat and to avoid additional consumption of fuel. Hot gases are also used to heat water supplied to the boiler drum 6 in a feed-water economizer (water heater) 8. Exhaust gases discharged into the atmosphere through a chimney stack are cleaned by electric filters 12.

Further processes occurring in a condensing steam-turbine plant are described below in a simplified form. Hot gases that are formed as products of combustion of pulverized fuel within the boiler flow over the boiler drum and convert the boiler water into steam which arrives at a steam reheater 7 wherefrom it is passed to the turbine 18.

Upon leaving the turbine, the dump steam is passed to a condenser 19 wherein it is converted into condensate by coming in contact with tubes of cold circulating water supplied through a pump 17 from a shore pump plant. The pump 21 forces the condensate to the deaerator 15 wherefrom it is passed through a water heater 13 to the economizer 8 and reaches the boiler drum 6 again, thereby completing the closed-circuit cycle.

Feed water supplied to the boiler is also heated in the water heater and deaerator by steam extracted from the reheat stages of the steam turbine. Such an arrangement has made it possible to raise the efficiency of the steam-turbine power plant.

The heat-electric generating plants depend for their operation on the same principle as the condensing plants, the only difference being that the former also supply their neighbouring power consumers (actually, within the radius of up to 20 km) with thermal energy in the form of steam and hot water. For heating, use is made of steam extracted from the reheat stages of the turbine at an appropriate pressure and temperature. This steam is delivered directly to steam consumers or to a heating boiler house for heating the water to be supplied to the hot-water systems.

The prime mover of a steam-turbine plant is a steam turbine. The turbine is coupled to a turbogenerator wherein mechanical energy of the rotating part is converted into electric energy.

The turbogenerator of a steam-turbine plant (Fig. 2) is a horizontal-shaft machine with its shaft 2 coupled to the steam turbine shaft via a half-coupling 1.

The turbogenerator consists essentially of a stator, a rotor, and an exciter.

The frame of the stator 4 accommodates an iron core that functions as a magnetic circuit. The generator frame is a robust structure made of steel plates lined on the outside with steel sheets. The sheet steel lining consists of two sections, one being welded to the frame and the other, a detachable piece. Cooling ducts passing circulating air are made between the lining and the core.

The core 3 is built up of a number of laminated stacks that are assembled of varnish-coated stampings. The stator stacks are spaced at a certain distance from each other to form cooling ducts for passing cooling air to the generator core and windings. The core is compressed and braced together on both ends with clamping bolts and hold-down strips made of a nonmagnetic material.

The stator slots accommodate a double-layer winding made of rectangular-section insulated copper strips. The winding leads are brought out on both ends of the core and connected into a three-phase winding with concentric end windings.

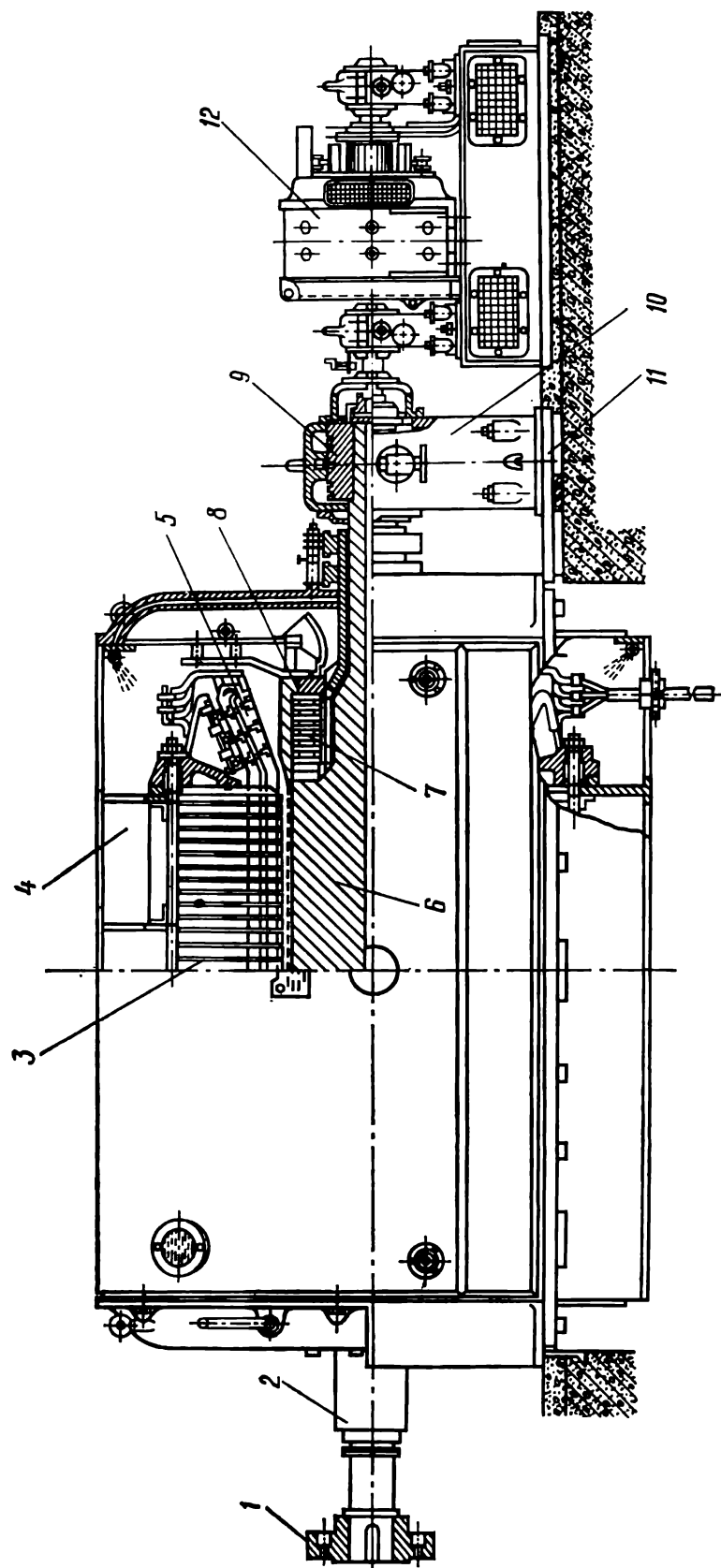


Fig. 2. Turbogenerator

1—half-coupling; 2—shaft; 3—core; 4—stator; 5—stator; 6—rotor; 7—rotor winding; 8—banding ring; 9—generator bearing; 10—bearing pedestal; 11—bedplate; 12—exciter

5. The strips are held in position within the core slots by shaped wedges made of an insulating material.

The turbogenerators are furnished with an open-circuit or a closed-circuit ventilation to cool down the core and windings that run hot while the machine is operating. An open-circuit ventilation system is that in which cooling air is admitted into the generator from the outside, passed over cooling ducts, and exhausted outside. In a closed-circuit system, cooling air circulates within the generator in a constant amount and is cooled down by an air cooler.

The iron core and the winding accommodated in its slots are cooled as follows. Heat liberated by the stator copper is dissipated through the strip insulation by air passing through radial cooling ducts of the core and through the air gap between the stator and the rotor. In the action, some portion of heat is transferred from the insulated surface (within the cooling ducts) but the largest amount of hot air is first delivered to the core teeth and only then reaches the air cooler. The core teeth are the hottest spots of the stator core as they take the winding heat and, being smaller in size, they have a rather high flux density and, hence, losses due to nonuniform flux distribution are greater in them.

Hydrogen-cooled turbogenerators are provided with gas coolers placed at the butt ends of the stator.

The cylindrical portions of the turbogenerator stator are covered with detachable end shields with the rotor shaft extensions brought outside through them. Where the shaft extensions leave the generator stator frame, there are oil seals that afford hermetic sealing of the generator frame and prevent hydrogen leakage.

The turbogenerator rotor 6 is a solid forged steel barrel with slots milled in it to receive a winding 7. The winding is secured within the slots by wedges made of duraluminium or any other nonmagnetic material to prevent closure of the rotor leakage flux through them.

The end portions of the rotor winding are held in position by banding rings 8 that prevent the rotor end windings from being carried away under the action of centrifugal forces set up due to a fast running rotor.

The rotor is mounted in outside bearings 9 that are accommodated in pedestals 10 installed on a bedplate 11.

The pedestal is insulated from the bedplate by insulating spacers to prevent current circulation over the shaft-bearings-bedplate circuit. Such a bearing current may appear due to the absence or breakdown of a spacer, and also due to a voltage built up across the shaft ends as a result of asymmetric stator field that may be caused by asymmetric magnetic reluctance on the path of the main flux, or by a nonuniform air gap between the stator and the rotor.

Heat liberated by the rotor copper passes through the insulation, then through the rotor barrel, teeth, and slot wedges (and also through the banding rings in the end connections) and is dissipated from the rotor surface by cooling air.

A direct current is required to excite a three-phase synchronous generator by setting up a revolving field as it flows through the rotor winding of the running machine. An exciter 12 functions as a d.c. source. The exciter is mounted on a separate bedplate. The armature shaft of the exciter rotates in its separate bearings and its shaft extension is coupled to the turbogenerator rotor shaft.

Exciting current can also be obtained from mercury-arc or semiconductor rectifiers.

The turbogenerators of modern steam-turbine power plants are noted for a unit capacity as high as 500 and 800 thousand kW. Under construction are machines of still higher capacity, such as a 1,200-MW generator constructed for the Kostroma steam-turbine power plant.

1.2.3. Nuclear Power Plants

A nuclear power plant greatly resembles the above-described steam-turbine plant as far as processes occurring in it are concerned. The difference is that the boiler unit is replaced by an atomic reactor and a steam generator.

Nuclear power plants use the heat liberated within an atomic reactor as a result of a nuclear chain reaction of some fissionable materials. Fissionable materials used in atomic reactors are called fissionable material fuels. Most useful for the purpose are uranium-235 and plutonium-239.

The heat portion of a nuclear power plant comprises two circuits. The first circuit passes circulating heat carrier and the second circuit conducts heat from the steam plant.

The heat carrier is water circulating at a pressure of 100 kPa and heated within the tubes of the reactor channels up to 540 K. In the second circuit, distilled water contained in the steam generator vaporizer begins to vaporize under the action of the heat carrier and is converted to steam pressurized to 12.5 kPa and delivered first to the superheater and then to the turbine.

A further circulation process is similar to that occurring in a steam-turbine power plant: dump steam extracted from the turbine arrives at the condenser wherein it is converted into condensate which is pumped to the deaerator and then to the steam generator heater and vaporizer.

The working reactor of the nuclear power plant renders the heat carrier, the channel tubes, and the parts and structures within the reactor core and nearby radioactive. All these parts emit radioactive rays that are dangerous to human life.

A double-circuit arrangement makes it possible to avoid induced radioactivity and to keep radioactive steam within the reactor.

Water flowing over the first circuit and passing through the reactor is radioactive. Therefore, all pieces of equipment of the first circuit are accommodated in special cells furnished with anti-radiation facilities.

The reactor is surrounded by a layer of protective water, concrete, and iron to ensure safety and appropriate biological protection, the total thickness of the protective layer being several metres.

Nuclear power plants have found wide application in the USSR. One of the advantages of nuclear plants that makes them so popular is a very small amount of fissionable fuel required for their operation. A power plant of 100 MW capacity, for example, consumes not more than 1 kg of fissionable materials a day.

Planned for the construction in this country in the recent future are large nuclear power plants with fast-neutron reactors. The capacity of some turbogenerators of such power plants will amount to 500, 800, 1,200, and even 1,500 MW.

1.2.4. Hydroelectric Power Plants

Hydroelectric power plants utilize the energy of falling water, the work derived from the water in falling through a given head being equal to the product of the water mass to the water height.

A more complete utilization of water resources on separate sections of a river is afforded by dams and water reservoirs that are constructed to ensure the required head for a cascade of power plants.

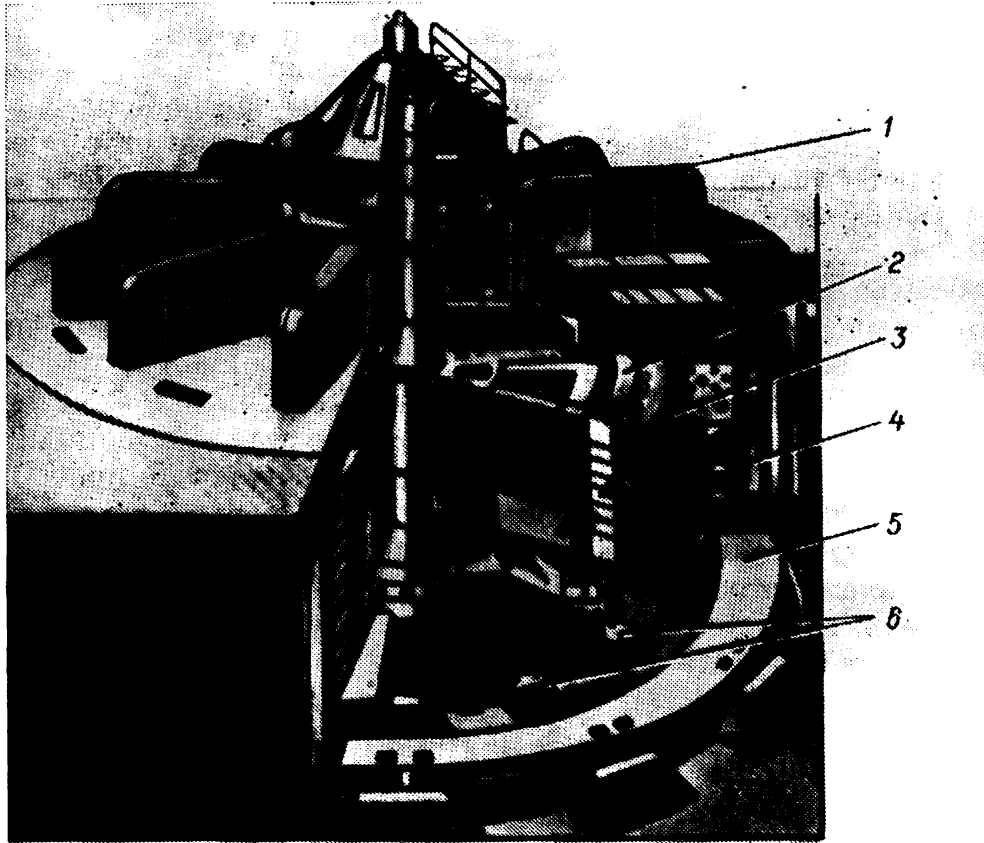


Fig. 3. Water-wheel generator

1—top spider; 2—rotor and poles; 3—stator; 4—air cooler; 5—bedplate; 6—lugs

Capacity P (kW) of each hydroelectric power plant incorporated in a cascade will be approximately proportional to the water discharge through installed turbines and to the head created, that is,

$$P \approx 9.81 \times QH\eta$$

where Q is water discharge, m^3 ; H is water head, m; η is turbine efficiency.

The main elements of any hydroelectric power plants are a water-wheel generator and a hydraulic turbine.

The water-wheel generator consists of a stator and a rotor (Fig. 3). The stator and its winding are almost similar in design to those of a turbogenerator, the difference being in the core length and in the number of slots.

The water-wheel generators are vertical-shaft machines furnished with a step bearing and a guide bearing.

The step bearing is designed to take axial thrusts exerted by the mass of rotating parts of the generator and turbine and by the reaction of water flowing over the turbine vanes. The step bearing is essentially a thrust bearing. It is mounted

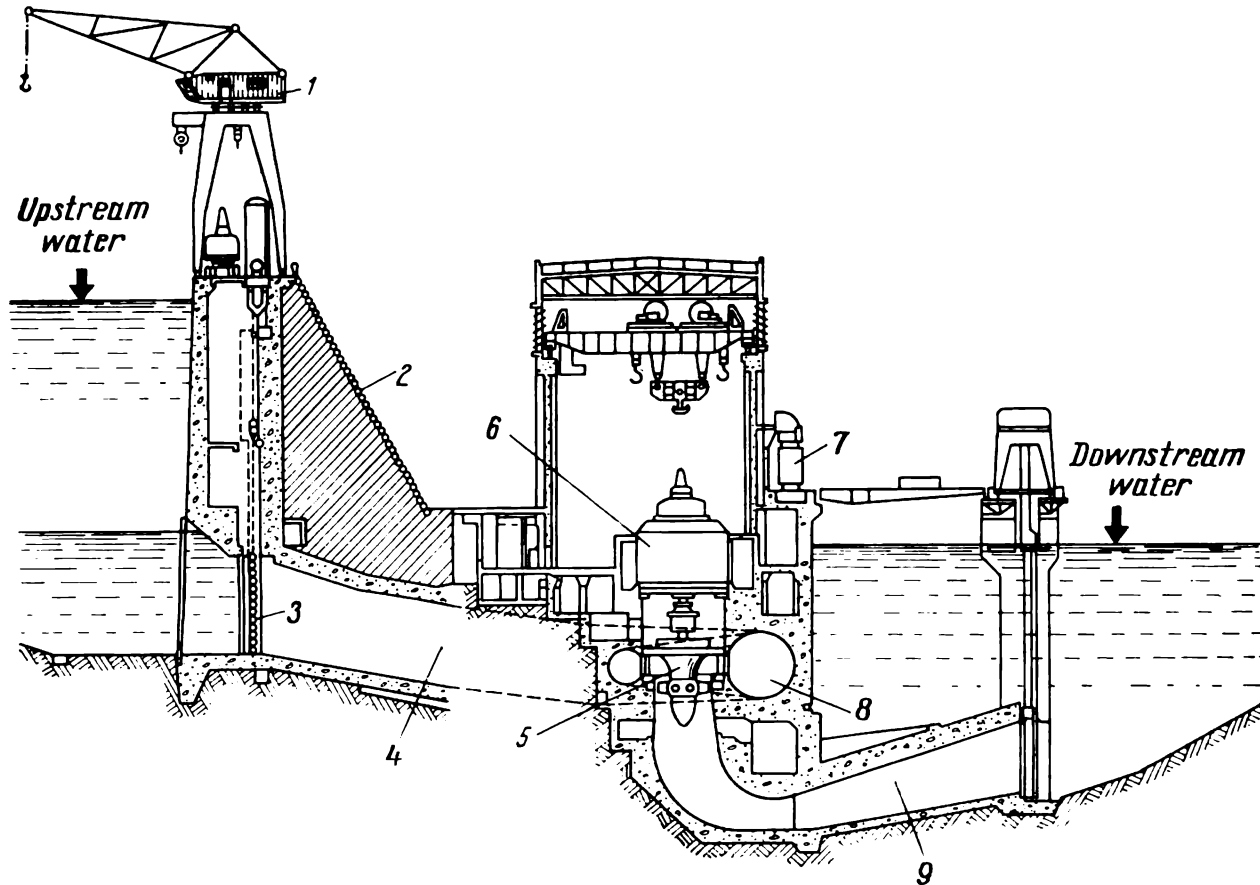


Fig. 4. Hydroelectric power plant. Sectional view

1—apron hoist; 2—dam; 3—apron; 4—penstock; 5—hydraulic turbine; 6—water-wheel generator; 7—transformer; 8—scroll case; 9—draft tube

either on the top spider 1 above the rotor 2 (an overhung arrangement) or on the bottom spider below the generator rotor (umbrella type arrangement).

The generator stator 3 is fitted with an air cooler 4 that affords cooling of the stator hot parts and winding.

The generator rotor 2 consists of a number of poles secured to a rim that is joined through arms to a shaft-mounted hub. Each pole is a solid or laminated core with pole shoes and coils. Each coil is a single-tier winding made of copper strips wound on edge. The coils are reliably insulated from the core. Laminated cores of large water-wheel generators are furnished with cooling ducts. The external surface of the bottom rim mounts brake segments that function to stop the brake shoes installed on lugs 6 as the rotor slows down.

Some water-wheel generators are furnished with a damping winding which is essentially a number of solid brass or bronze bars placed on both sides of the pole and interconnected by junction strips. The damping winding functions to reduce heating of the field coils and cores by double-frequency currents induced in them when the generator carries an unbalanced load. It also reduces electromechanical oscillations that may occur due to sudden fluctuations of load or short circuits.

The water-wheel generators are installed in turbine halls of powerhouses.

Most popular is a reservoir hydroelectric power plant that is illustrated by Fig. 4 (cross-sectional view).

The upstream water in front of the dam 2 is delivered over a penstock 4 to a scroll case 8 wherefrom it is passed to the runner blades of the hydraulic turbine 5. The scroll case is of a varying section so that water is gradually supplied to the turbine runner.

Water is discharged from the turbine through a draft tube 9 to the tailwater canal. An apron 3 is used to control the amount of water supplied to the turbine and to shut off water supply whenever necessary.

As compared to thermal power plants, hydroelectric ones are noted for the following advantages:

- possibility of full automation of governing and operational processes;
- high efficiency amounting to 80 per cent;
- low cost of each kilowatt-hour of electric energy generated.

1.3. Power Transmission Lines and Substations

Power transmission lines and substations are important components of electrical networks and power systems or grids that include a number of power plants to utilize their power to better advantage.

A *power system* consists of a number of power plants, substations, power transmission lines, and heating mains interconnected and coordinating their operations with respect to proper distribution and uninterrupted supply of electric and heating energy.

An *electrical network* consists of generators, switchgear installations, electric circuits, substations, and power receivers.

A power system makes it possible to provide for maximum utilization of the capacity of each power plant incorporated and to dispense with stand-by equipment. Besides, power systems are characterized by a more uniform load curve free from sudden fluctuations of load, which is most useful and suitable for the power plants. A still better operation, as far as economic and duty considerations are concerned, can be obtained by interconnecting two or more power systems into a power grid. A power grid enables coordination of the operation of distant power systems so that peak loads during maximum demand hours are smoothed down, especially in regions lying from west to east.

Eleven power grids are now functioning in the USSR. Under construction is an integrated power grid of the USSR that will interconnect all the power systems of the country. The integrated power grid of the European part of the USSR is already

in operation. It includes seven power grids incorporating about 600 power plants of a total capacity of 120 mln kW.

Power plants and systems are interconnected through high-voltage power transmission networks, step-up and step-down substations. A simplified diagram of Fig. 5 illustrates how power plants are interconnected to form a power system.

As is seen from the diagram, power plants *A*, *B*, *C*, *D*, and *E* are interconnected through 220-kV power transmission lines. Electric power is transmitted and distributed at high voltages of 220, 110, 35, and 10 kV, while power consumers operate on voltages of 0.4 and 0.23 kV. The power supply system provides for mutual reserving of substations on all the voltage levels, which makes the system more flexible and eliminates interruption of power supply to consumers upon the occurrence of a failure in networks or substations and also when some of the substations or networks are to be disconnected for scheduled maintenance or repairs.

Electric power produced by generators at a voltage of usually 10.5 kV is applied to the main busbars of the power plant switchyard and then to the switchgear of the step-up substation. The step-up substation comprises two-winding and three-winding transformers that function to raise the voltage to 35, 110, and 220 kV and higher still. The high-voltage power is then transmitted at one of these voltages to the step-down substations. Connected to the busbars of the substations are also the power transmission lines of adjacent power plants of the system (the so-called junction lines).

Step-down transformers reduce the voltage to 10 or 6 kV and at this voltage the power is supplied to distribution centres and transformer substations of power consumers. The latter take power at a voltage of 0.4/0.23 kV off the transformer substation busbars.

High voltage is required for power transmission to minimize power loss in transmitting lines and to reduce cross-sectional area of power transmission line conductors.

As is known, power loss in the transmission line conductors depends on the conductor current and resistance:

$$P = I^2 r$$

where I is current, A; r is line conductor resistance, Ω .

In order to reduce power loss in the line, at the same time retaining the same magnitude of power transmitted, it is necessary to reduce the current through conductors because power loss in the line is proportional to the square of current. So, for example, a 90% reduction of current will reduce power loss in the line by about 99%. The current through the line can be reduced by appropriately increasing the voltage since for a given power the current is inversely proportional to the voltage. In other words, current through the line will decrease with an increase in voltage at the same power.

The greater the distance between the power generating plant and the power consumer, and the heavier the power transmitted, the higher is the voltage required for power transmission.

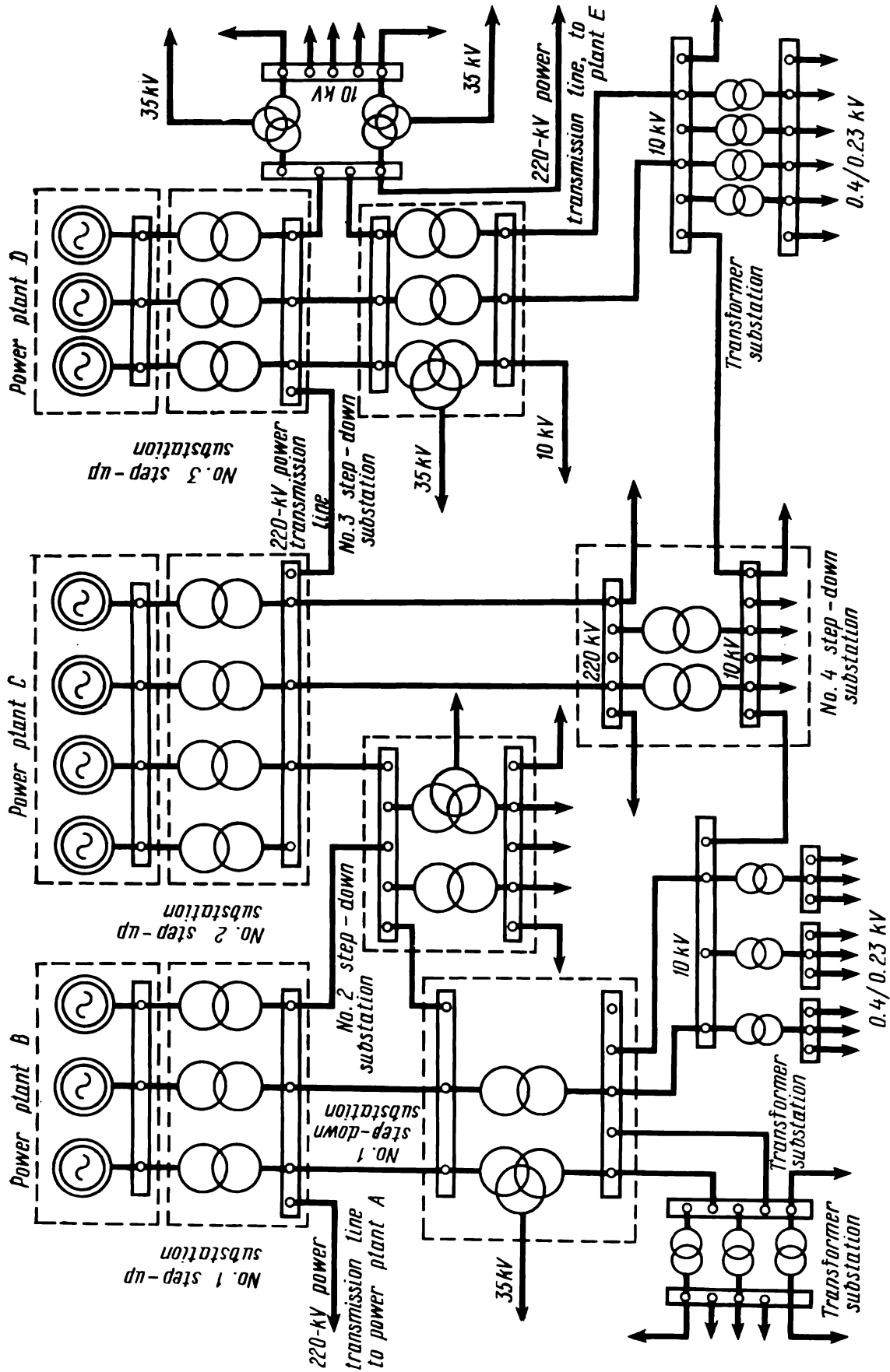


Fig. 15. Power system schematic diagram

Power generation, transmission, distribution, and consumption are to be made at definite voltage magnitude, the so-called rated voltages. Rated voltages are specified by the USSR State Standard GOST (see Table 1).

Power is usually distributed to consumers at voltages of 10,000, 6,000, 660, 380, and 220 V.

Table 1

Rated Voltages of Power Receivers, Generators, and Transformers (GOST 721-62)

Rated voltages of power consumers, V				Rated terminal voltages, V			
d.c.	three-phase, 50 Hz		single-phase, 50 Hz	generator		transformer	
	between lines	to neutral		d.c.	three-phase, 50 Hz, between lines	three-phase, 50 Hz, between lines	
						primary	secondary
6	—	—	—	—	—	—	—
12	—	—	12	—	—	—	—
24	—	—	24	—	—	—	—
36	36	—	36	—	—	—	—
48	—	—	—	—	—	—	—
60	—	—	—	—	—	—	—
110	—	—	—	115	—	—	—
—	—	—	127	—	—	—	—
220	220	127	220	230	230	220	230
440	380	220	380	450	400	380	400
	660	380	—	—	690	660	690
	3,000	—	—	—	3,150	3,000 & 3,150	3,150 & 3,300
	6,000	—	—	—	6,300	6,000 & 6,300	6,300 & 6,600
	10,000	—	—	—	10,500	10,000 & 10,500	10,500 & 11,000
	20,000	—	—	—	21,000	20,000 & 21,000	21,000 & 22,000
	35,000	—	—	—	—	35,000	38,000
	110,000	—	—	—	—	110,000	121,000
	150,000	—	—	—	—	150,000	165,000
	220,000	—	—	—	—	220,000	242,000
	330,000	—	—	—	—	330,000	347,000
	500,000	—	—	—	—	500,000	525,000
	750,000	—	—	—	—	750,000	785,000

1.4. Distribution Centres and Transformer Substations

1.4.1. Distribution Centres

A *distribution centre* is essentially a substation designed for the reception and distribution of electric energy to power consumers without conversion and transformation of voltage supplied. Modern distribution centres rated 10 and 6 kV are built up of so-called metal-enclosed cubicles (KCO) or metalclad switchgear cubicles (KPY) available of stationary and draw-out models.

The metalclad and metal-enclosed cubicles of all the models accommodate all the necessary circuit-opening and protective devices, instruments, and associated

pieces of equipment according to the circuit arrangement adopted with all the internal connections of power and auxiliary circuits.

One of the most popular stationary metal-enclosed cubicles is type KCO-266 cubicle available of 22 design alternates distinguished by the connection of primary circuits. Cubicles accommodating oil circuit breakers differ by the type of operating mechanism employed (manual, spring-loaded, electromagnetic), type of relay protective gear, number of current transformers, and ratings of electrical equipment installed therein.

Figure 6a illustrates cubicle KCO-266 of a stationary model incorporating an oil circuit breaker. The cubicle is divided into three compartments. The upper compartment *I* accommodates support insulators *1* with collecting busbars *2* and a busbar isolator (sectionalizing switch) *3* with a bushing insulator *4*. The middle compartment *II* houses an oil circuit breaker, and the lower compartment *III*, a line isolator. The partition between the middle and the lower compartments *II* and *III* mounts current transformers *6*.

The face side of the cubicle has two doors (an upper and a lower one) as wide as the face. The upper door carries secondary switching devices and terminal strips closed with a special cover. The upper door is closed with a lock and has no interlocking mechanism. It can be opened for the inspection of the oil circuit breaker without de-energizing the cubicle as there is a screen guard behind it that is keyed and interlocked with the operating mechanisms *8* of both the isolators. The lower door is closed with a lock and interlocked with the busbar isolator.

A light panel *9* displaying the purpose of the cubicle is fitted on the top over the entire width of the face. The panel lamps function also to illuminate the interior of compartment *I* and the switchgear compartment.

Welded at the centre of the face side is a band carrying operating mechanisms *8* of the isolators and an operating mechanism *7* of the oil circuit breaker.

The KCO cubicles are furnished with a number of interlocking mechanisms. So, the busbar and line isolators in the cubicle shown by Fig. 6a cannot be opened as long as the oil circuit breaker is on; with the busbar or line isolator closed, the screen door cannot be opened; with the screen door open, neither the busbar isolator nor the line isolator can be closed; with the busbar isolator closed, the lower compartment door will not open; with the lower compartment door open, the busbar isolator will not close; earthing blades cannot be cut in while the line isolator is closed; the line isolator cannot be closed while the earthing blades are cut in.

Interlocking mechanisms used in the KCO cubicles ensure the desired safety for attending personnel; they make it impossible for the personnel to reach the compartments and live parts accommodated therein with the exception of cases when an operation is meant to be made on live equipment, such as in the case of phasing out or replacement of fuses.

The series KPY2-10Π metalclad switchgear cubicle of the draw-out model is illustrated by Fig. 6b. This cubicle is distinguished by a draw-out truck.

All the pieces of equipment incorporated in the switchgear cubicle are accommodated in five compartments *I* through *V* separated by steel partitions. Compartment *I* accommodates a draw-out truck, compartment *II* houses a current transformer *6*, an earthing transformer *10*, an earthing isolator, and cable terminations.

The primary busbar sectionalizing contact is located in compartment *III*, and support insulators *1* and busbars *2* are in compartment *IV*. Compartment *V* accommodates secondary circuit devices.

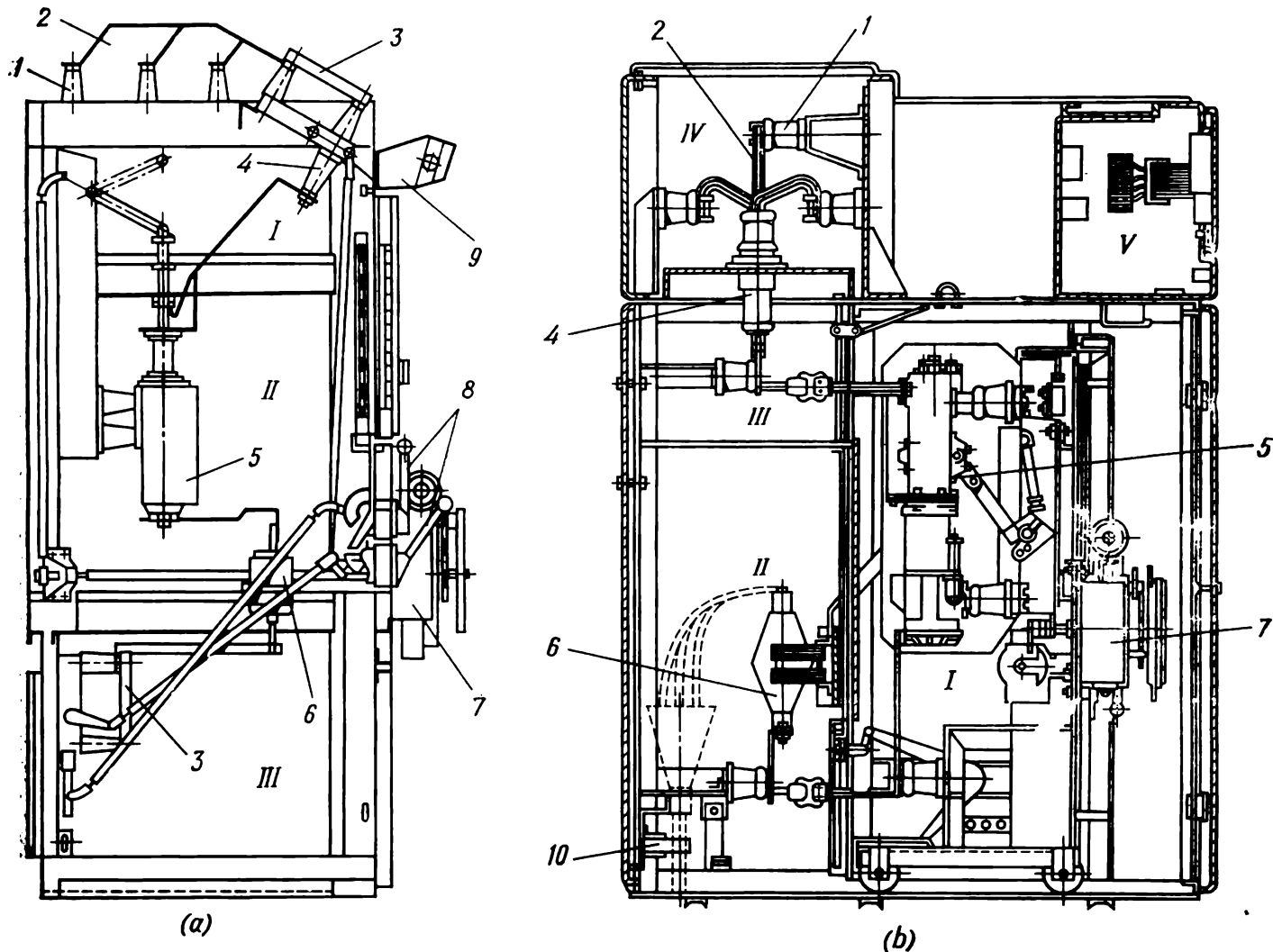


Fig. 6. Metalclad switchgear cubicles for indoor mounting

a—type KCO-266 stationary design alternate; *b*—type KPY2-10Π draw-out design alternate; *1*—support insulators; *2*—collecting busbars; *3*—isolators; *4*—bushing insulators; *5*—oil circuit breakers BMΓ-133 and BMΠ-10K; *6*—current transformers TΠΠ-10; *7*—operating mechanisms ΠΠΠ-10; *8*—isolator operating mechanisms; *9*—light panel; *10*—earthing transformer

The truck is drawn out from the repair to the test position by means of handles fitted on its front panel, and from the test to the repair position by means of a worm gear drive.

The KPY2-10Π metalclad switchgear cubicles are meant for two-sided service.

The metal-enclosed and metalclad switchgear cubicles of other models, such as KCO-366, KPY2-10Θ, K-VIII, etc., are distinguished from those described above by the type of electrical equipment incorporated, their characteristics and make-up.

1.4.2. Transformer Substations

A *transformer substation* is an electrical installation designed to transform and distribute electric power. It consists of transformers, switchgear for up to 1000-V service and higher still, a storage battery, control devices, and auxiliary structures.

Recent trend has been to use unit transformer substations (КТП) of indoor or outdoor installation for feeding industrial enterprises.

An indoor two-transformer unit substation is illustrated by Fig. 7. It consists of separate butt-to-butt cubicles (Fig. 7a). Layout of electrical equipment within each cubicle is shown by Fig. 7b and the elementary circuit diagram is given in Fig. 7c. The 10-kV line bushings and the oil circuit breaker are accommodated in No. 1 extreme cubicle. The next cubicle houses a power transformer of 100 to 400kW capacity (type TCM air-cooled or type TM-oil immersed). The circuit-breaker cubicle mounts busbars and the main circuit breaker rated up to 1000 V (air circuit breaker BA-2050 or A-3100).

The line circuit-breaker cubicle incorporates from 3 to 12 circuit breakers, such as type BA-2030H, for outgoing lines.

The middle A6 circuit-breaker cubicle accommodates a sectionalizing circuit breaker. The electrical equipment of the remaining four cubicles is arranged in the same manner.

The transformer substation is noted for easy maintenance and flexible circuit arrangement. For example, upon voltage failure in the left-hand section transformer the main circuit breaker of this transformer opens, the normally open sectionalizing circuit breaker closes and recovers voltage of the section.

Outdoor unit transformer substations are built up of preassembled and fully wired metal cubicles (КТПН) or prefabricated ferroconcrete elements (БКТП).

БКТП is a substation composed of two prefabricated ferroconcrete units No. 1 and No. 2.

No. 1 and No. 2 units are ferroconcrete vaults accommodating power transformers each up to 400-kVA and a switchgear. All pieces of equipment are installed and wired at the factory and supplied to the installation site (without transformers). Units as heavy as about 14 t are mounted on a foundation, that has been made ready to receive them, by means of a truck-mounted crane of appropriate load-carrying capacity. Both the units are similar in design and layout of equipment.

The two-transformer БКТП substation employs a standard two-way circuit with additional 600-A three-pole isolators installed on the low-voltage side of power transformers. Each unit (No. 1 and No. 2) is a vault with a single entrance door and two concrete barriers.

The 10-kV switchgear is an assembly designed for five connections, using single-pole isolators. It is isolated from the power transformer section with a concrete barrier and provided with a metal screen door. The switchgear rated up to 1000 V incorporates an automatic reclosing station, and a series ШОБ-59 switchboard built up of seven series БПБ-2 and БПБ-4 (cutout-switch) units. It is separated from the transformer section with a concrete barrier. Cooling ports are provided in the floor and in the doors to admit cooling air to the transformer.

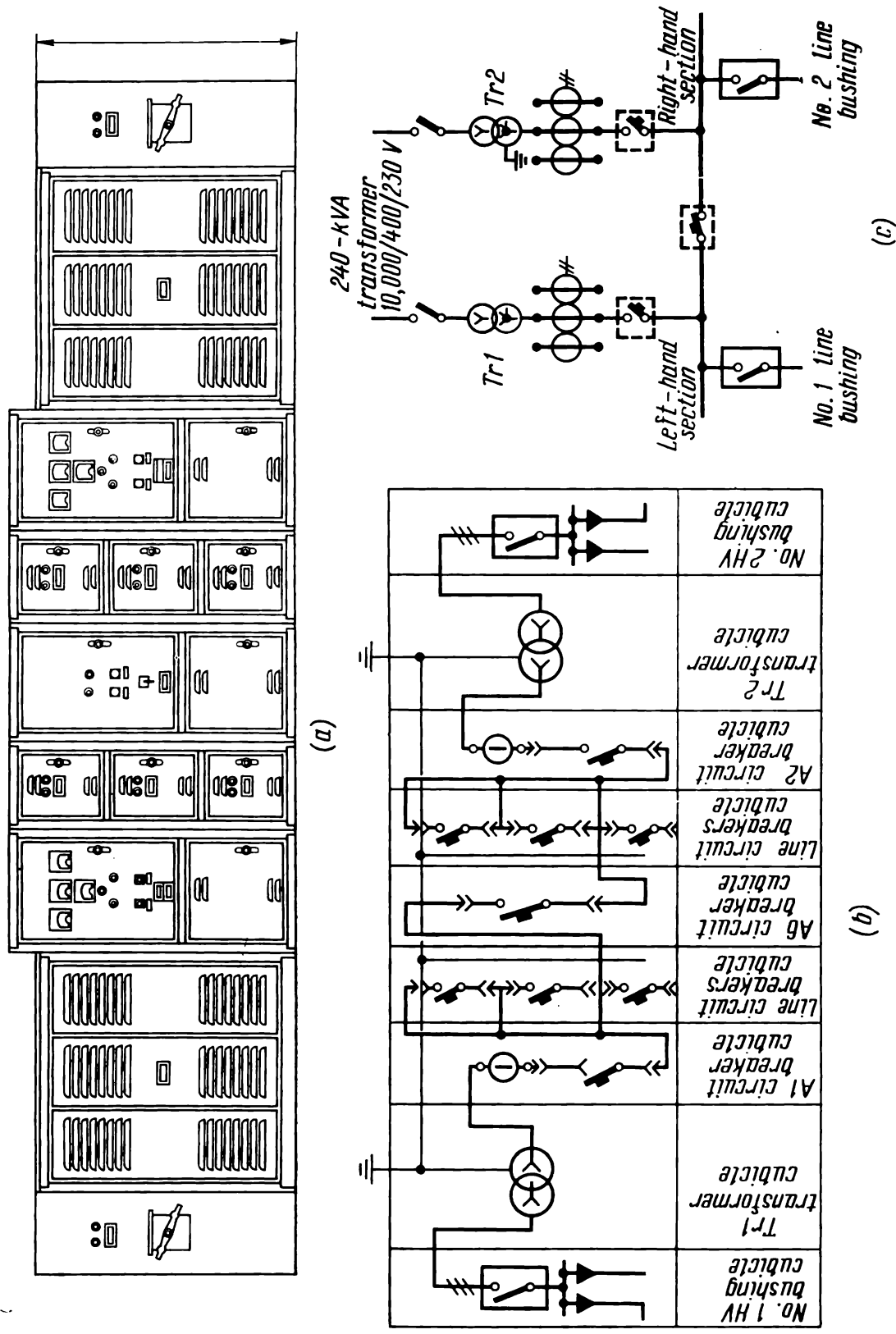


Fig. 7. Unit transformer substation
a—general view; b—arrangement of equipment; c—elementary circuit diagram

The BKTII substation can likewise be used as a single-transformer substation whenever necessary. When this is the case, only one unit is supplied on site and mounted on the foundation.

Metalclad and metal-enclosed cubicles and prefabricated units make it possible to install and wire distribution centres and transformer substations by industrialized methods, thereby cutting down the installation cost and time.

1.5. Electrical Locations

Electrical locations are premises or bays accessible for attending personnel only and accommodating operating electrical equipment intended for the production, conversion, or distribution of electric energy.

Electrical locations are classified by the Regulations for Electrical Installations according to explosion hazard, fire hazard, and electric shock safety.

1.5.1. Classification of Locations According to Explosion Hazard

Explosion-hazard locations are those wherein the following explosive mixtures may be formed in the process:

(a) combustible gases or fumes with air or oxygen, or other gaseous oxidizers, such as chlorine;

(b) combustible dusts or fibres with air when they are in a suspended state.

Explosion-hazard locations and installations are divided into six Classes.

Class B-I includes locations where combustible gases and fumes are liberated in such an amount and possess such properties that they are liable to form explosive mixtures with air or some other oxidizing agents under normal short-time duty conditions.

Class B-Ia includes locations where explosive mixtures of combustible gases or fumes and air or any other oxidizing agents are not formed under normal conditions and may appear as a result of accidents or faults.

Class B-Ib locations are similar to those of Class B-Ia but are distinguished from the latter by one of the following features:

(a) combustible gases contained in these locations have a high value of lower explosive limit and a strong smell at maximum concentrations permitted by sanitary standards (such as compressor halls of ammonia compressor plants and absorption refrigerators);

(b) explosive concentration of gases may occur only under abnormal conditions;

(c) combustible gases and easily inflammable liquids are contained in a small amount and do not form explosive concentrations; moreover, open flame is not used in the premises. Such premises are considered nonexplosive if operation is carried out in exhaust hoods or under exhaust sheds.

Class B-Id locations include outdoor installations containing explosive gases, fumes, combustible and easily inflammable liquids (such as gas tanks, gas holders, filler and drain platforms, etc.), where explosive mixtures may occur under abnormal conditions only.

For outdoor installations, explosive regions are those located:

(a) at a distance of up to 20 m in the horizontal and vertical planes from the point of open drain and fill (for platforms where easily inflammable liquids are handled in the open);

(b) at a distance of up to 3 m in the horizontal and vertical planes from enclosed explosive facilities, and up to 5 m in the horizontal and vertical planes from breathing and safety valves (for other installations).

Outdoor open platforms with pipelines for combustible gases and easily inflammable liquids are classified as nonexplosive locations.

Class B-II locations include premises where the atmosphere contains inflammable dusts or fibres in a suspended state that are capable of forming, together with air and miscellaneous oxidizing agents, explosive mixtures under normal short-time operating conditions.

Class B-IIa locations are premises where explosive mixtures indicated for Class B-II locations can be formed under abnormal conditions only.

1.5.2. Classification of Locations According to Fire Hazard

Fire hazard locations include premises or outdoor installations where inflammable materials are stored or used. They are classified as locations of Classes II-I, II-II, II-IIa, and II-III.

Class II-I includes premises where inflammable liquids liberating vapours with a flash point over 45°C are stored or used (such as stores of mineral oils, mineral oil conditioning plants, etc.).

Class II-II and II-IIa incorporate industrial premises and stores containing solid or fibrous inflammable materials (such as wood, fabrics, etc.).

Class II-III incorporates outdoor installations where combustible liquids liberating vapours with a flash point over 45°C or solid inflammable materials are stored or used (such as open stores of mineral oils and the like, or coal, peat, and wood stores).

Industrial premises, though not accommodating fire or explosion hazard equipment or materials, but are adjacent to explosion hazard locations, shall be included in this or that Class according to the following considerations:

if premises are adjacent to Class B-I, B-Ia, or B-II locations and are separated from them with a single wall having a door, such premises are one Class lower, that is, B-Ia, B-Ib, or B-IIa, respectively;

if premises are adjacent to Class B-Ib and B-IIa explosion hazard locations and are separated from the latter by a single wall with a door, or they are adjacent to Class B-I, B-Ia, B-II locations and are separated from the latter with two walls and doors forming a passageway or a corridor, such premises are considered non-hazardous in respect to fire and explosion.

When this is the case, the walls separating the premises shall be made of incom-bustible materials and the doors are to be fireproof and shall open in the direction of less hazardous premises.

Passageways between the walls shall be narrow enough to make it impossible to open one door while the other one is open.

The exhaust-fan chambers servicing explosion hazard premises and isolated from

the latter are classified as explosion hazard locations one class lower than the premises serviced by them.

The class of explosion and fire hazard locations shall be determined by technologists and electricians of the design or operating organization. The locations are classified on the basis of physical and chemical properties of vapours and gases contained therein and also on the basis of their expected content in the premises, quality of ventilation, etc.

A proper classification of locations according to environmental conditions, explosion and fire hazard is very important as the class of locations determines the type of cables and wires, methods of their laying in premises, design forms of fittings and electrical equipment (such as hermetically sealed, drip-proof, explosion-proof, etc.).

In determining the degree of fire hazard due consideration is given to the inflammability of structural materials and building components used in the premises. By their inflammability they are divided into three groups:

Group 1 includes incombustible materials, such as natural and synthetic inorganic mineral materials and metals;

Group 2 includes hard-combustible materials composed of incombustible and combustible materials, such as hydrosol, asphalt concrete, gypsum parts with fittings made of organic materials or with fillers, gypsum lining plates, straw-and-clay materials of at least 900 kg/m³ mass by volume, antipyrene treated wood, felt soaked in clay solution, linoleum, concrete with organic fillers (xyloconcrete, and the like), fibrolite;

Group 3 incorporates combustible materials, such as organic materials not treated with fireproof compounds.

Table 2 gives materials and constructions characterized by their combustibility.

Table 2

Combustibility group	Characteristics according to combustibility	
	materials	constructions
Incombustible	Do not catch fire nor smolder under the effect of open flame or high temperature	Those made of incombustible materials
Hard-combustible	When exposed to open flame or high temperature, they catch fire, smolder, or char with difficulty and stop to do so as soon as flame source is removed	Those made of hard-combustible materials and constructions made of combustible materials and shielded by plaster or incombustible lining
Combustible	Readily catch fire or smolder under the effect of open flame or high temperature and keep to do so upon the removal of the source of flame or high temperature	Those made of combustible materials and not shielded with plaster or incombustible lining

1.5.3. Classification of Locations According to Electric Shock Safety

Locations considered as dangerous in respect to electric shock are characterized by one of the following factors: moisture or conducting dust; conducting floors (metal, earth, ferroconcrete, brick, etc.); high temperature; danger of accidental contact for the attending personnel to earthed metal structures, pieces of equipment, mechanisms, etc. contained in the premises on one side and to metal bodies of electrical equipment on the other side.

Extremely dangerous locations with respect to electric shock are characterized by one of the following conditions: high humidity; chemically active atmospheres; two or more conditions thereof existing simultaneously.

Electrically safe locations are those where conditions causing high or extremely high danger of electric shock do not exist.

1.6. Electric Power Utilization

Power consumers are supplied with electric energy at a voltage of maximum 1,000 V a.c. over a three-phase system incorporating transformers with an unearthed or solidly earthed neutral. The transformer neutral is the point of its star-connected winding where the voltage is equal in respect to all the external terminals.

Electric power consumers are electric motors driving miscellaneous machines and mechanisms, incandescent and fluorescent lamps, electric furnaces, electric plating baths, miscellaneous process facilities, welding sets, and the like.

Electric energy consumption involves its conversion back to mechanical, thermal, or thermal and luminous energy when used by electric motors, electric furnaces, and lighting lamps, respectively. Such conversions are accompanied by losses primarily in the form of heat dissipated in surrounding atmosphere.

Power is supplied at rated voltages specified by Table 1.

For electric motors and miscellaneous devices the rated voltage is determined as that sustained by their insulation and ensuring their trouble-free operation as guaranteed by the manufacturer. The electrical equipment rated voltage is always indicated on the nameplate of the respective piece of equipment (electric motors, devices, etc.) or on the trademark (relays, instruments, etc.).

All the instruments and devices shall be connected to supply sources of the same rated voltages only. This is an important requirement that must be strictly observed to ensure safety for insulation, trouble-free operation, and long service life of electrical equipment.

Modern enterprises, installation and construction sites also consume power for ancillary (home) needs in addition to driving, lighting, and heating purposes. Ancillary power amounts to hundreds of thousands and millions of kilowatt-hours.

The electric energy production involves the consumption of a great amount of fuel and labour of personnel attending power plants; power transmission and distribution require a great number of operating and maintenance personnel for power systems and substations.

There are many ways of how to save electric energy. In industry, for example, electric energy can be saved by cutting down the idle run of machines, normal loading of electric motors, proper maintenance of electrical equipment (renewal of bearing grease in due time, proper repair and maintenance of motors, etc.), by correctly conducting technological processes, etc.

A great amount of electric power can be saved in industrial plants by a proper selection of lighting fixtures and power of lamps installed in them, cleaning of lighting fittings and lamps from soot and dust in due time to maintain the luminous efficiency of lamps.

Electric energy can be saved at installation sites by cutting down the idle run of hoisting and haulage equipment, welding sets, soldering irons, etc.

Electric energy can practically be saved by any factory and at any installation or construction site. The reserves of power economy shall be found and used to the benefit of national welfare.

Review Questions

1. Describe the operation of a heating and power plant.
2. How is electric energy transmitted from a power plant to a consumer?
3. Describe a transformer substation.
4. What premises may be referred to as electrical locations?
5. How are electrical locations classified according to surrounding atmosphere?
6. How are locations classified according to electric shock safety?

Organization of Work, Industrialized Methods, and Equipment Used for Installation and Wiring

2.1. Organization of Electrical Work Methods

Well-organized electrical work is one of the basic conditions ensuring high productivity of labour, high level of production, minimum time and cost of work.

The electrical work execution plan (EWEP) is an essential document that will help to achieve the best organization of electrical work on large installation sites.

The electrical work execution plans for large installation sites using intricate electrical equipment are compiled by project organizations, and those for small sites by production and design departments of electrical installation boards. Standard EWEPs are worked out for installation sites built to standard projects.

The EWEPs for large installation sites (machine-building works, metallurgical concerns, etc.) usually contain three sections.

Section one is an instruction sheet containing:

- (a) information concerning the installation site;
- (b) characteristic, brief description, and schematic of the process;
- (c) general plan showing the layout of auxiliary and permanent structures and the approved diagram of electric power supply;
- (d) list of amendments introduced in reference drawings and estimates approved by the customer;
- (e) basic technical and economical characteristics given separately for electrical work and preparatory jobs;
- (f) basic requirements to be contained in the organization plan.

Section two contains the description of work organization procedures on the building site, such as:

- (a) methods of installation work;
- (b) recommendations on how to use miscellaneous hoisting and haulage mechanisms to increase labour productivity of electricians;
- (c) safety precautions to be observed while carrying out electrical work;
- (d) coordination of work between electricians and other contractors.

Section three contains:

- (a) list of materials and parts required for electrical installation work;
- (b) list of all pieces of equipment required for the execution of electrical installation and wiring on site and their detailed characteristics;
- (c) list of electrical facilities required for mounting auxiliary and permanent structures.

All these lists are to be compiled separately for parts supplied by factories and for those received from preassembly divisions.

The EWEPs of large and intricate enterprises are supplemented by a brief directory that includes:

- (a) situation plan of the construction site showing substations, distribution centres, buildings, and building components incorporating electrical equipment;
- (b) diagram of cable lines routed over the territory of the enterprise and beyond it;
- (c) diagrams of electric power supply of substations and factory shops;
- (d) plans of substations, factory shops, switch-houses, machine rooms, outdoor substations, overhead power transmission lines, showing reference marks, types of supporting structures and wire materials used.

The EWEPs may be brief or detailed. The contents of the EWEPs depend on a number of factors, such as size of enterprise, sub-contractors involved in the work, characteristics of distribution lines or electrical equipment, extremal working conditions (Far North or tropics), etc.

The EWEPs are discussed at the meetings of technical councils of installation organizations together with the representatives of project organizations, customer, and general contractor.

The EWEPs are to be approved by the chief engineer of the installation board and shall never be revised without his written admission.

In compiling an EWEP, bear in mind the following:

- (a) do not include data already given in other technical documents, such as the project, reference drawings, reference books, regulations, and instruction manuals;
- (b) in appended drawings and diagrams make use of symbols specified by state standards only (in the USSR, the GOST standard).

In mounting intricate electrical equipment on large sites, the best organization of work is achieved by using the so-called regional system. To this end, the entire site is divided into mounting regions in compliance with the scope and character of electrical work expected. A definite amount of work characterized by similar operations and completeness is carried out within each region.

Electrical work is to be done in strict compliance with the approved project of power supply system and electrical installations of the site. That is why, a well-organized work can be obtained through the clever project and high skill of electricians engaged.

The electrical installation project usually consists of an instruction sheet, an estimate, a parts list (including materials, outfit, various structures), single-line design circuit arrangements, floor plans, and other documents.

The instruction sheet contains technical and economic assignment of design considerations adopted by design engineers.

The estimate is a document determining the probable cost of electrical work.

The parts list contains the name, specifications, and quantity of pieces of equipment, building components, main and auxiliary materials required to complete the entire scope of electrical work on site.

The single-line design circuit arrangements for power distribution and supply of lighting and power consumers illustrate the adopted power supply system, loads

on separate sections of electrical networks, voltage drops across certain points.

The floor plans show the layout of main and distribution lines and busways; they specify types and cross-sectional areas of wires, busbars, and cables, and also show how to lay them. The floor plans also give the descriptions and illustrations of building components of each floor and separate elements of buildings, layout of embedded parts, raceways grooves, recesses, holes, and seats specially made while making the carcass of a building or contained in prefabricated parts (blocks, panels, slabs, etc.) and meant for routing electric wiring, installing switchboards, securing busbars, installing lights, etc.

In addition to the above-mentioned documents, various papers are drawn up in the course of installation and upon the completion of work. Among them are reports on concealed jobs and inspection of electrical equipment, on the installation and wiring of earthing systems, on the underground laying of cables, etc.

Preparations for electrical work are made upon the reception of the approved project. They are usually started from the acceptance of carcasses of buildings and building components to receive electrical parts. Buildings and their components are accepted by the representative of the electrical installation contractor or by the assigned chief in charge of electrical work along with the representative of the builder.

The acceptance officials shall check the following:

(a) raceways, trenches, recesses, and holes provided in the buildings and staircases and meant to route power networks for condition and for compliance with the project requirements;

(b) presence of finished and plastered surfaces in premises where open wiring is envisaged by the project;

(c) conditions for normal and safe electrical work along with building, plumber, and finishing jobs, or for their separate performance;

(d) conditions for safety of installed pieces of electrical equipment and for their protection against precipitation and damage in the course of building or finishing work.

An appropriate report is drawn up upon the acceptance of buildings or building components.

With the buildings and building components ready to receive electrical parts, the representatives of builders and electricians work out a common schedule of work so that electrical work can be in time coincidence with or somewhat lagging behind building jobs.

The common schedules are to be approved by the managers (chief engineers) of the building and electrical installation contractors.

Apart from common schedules, electrical work progress charts are drawn up for teams, installation sites, preassembly divisions and installation boards.

The progress chart is a schematic representation of operations and elements of a process, interrelations between them, and sequence of their execution. It is essentially a graphic model of the process illustrating all the elements of the process, viz., jobs, events, and interrelations thereof in the form of geometric figures and lines.

The starting elements of the progress chart are the job and the event.

The job is a certain process consuming time and materials and requiring various tools and devices for its execution.

The event is a result of one or more jobs, which makes it possible to start one or more next jobs.

Every job is started from and completed by an event. Every event, in its turn, may be a start or a finish of a job. One job may be associated with not more than two events.

In progress charts, events are usually shown by circles*, and jobs by arrows (lines).

Figure 8 illustrates a progress chart where event 1 is the start of jobs *A*, *B*, *C*, and events 2, 3, 6 are the results of these jobs. Events 2, 3, 6, in their turn, being

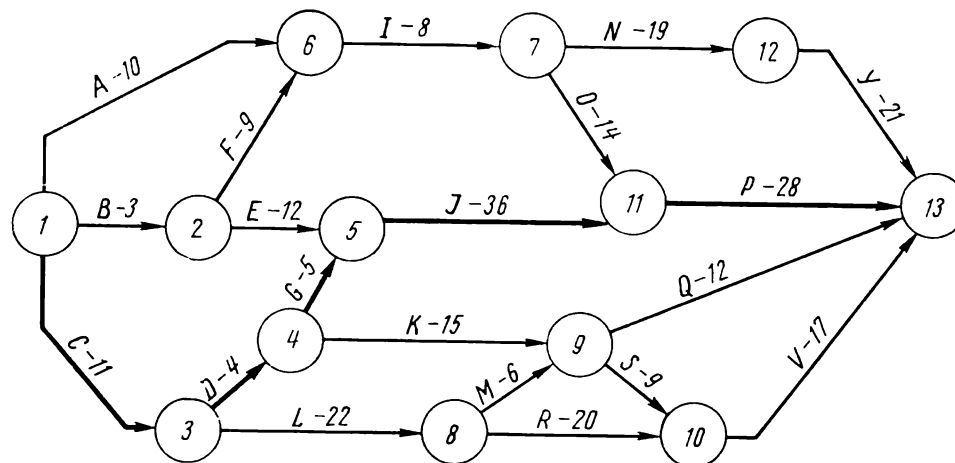


Fig. 8. Progress chart

the results of preceding jobs *A*, *B*, *C*, are at the same time starting events for jobs *D*, *E*, *F*, etc.

In drawing up a progress chart input and output jobs are to be distinguished. On the progress chart illustrated herein job *B* will be an input job for event 2 and jobs *F* and *E* are its output jobs. Jobs *F* and *E*, that are output jobs for event 2, will be at the same time input jobs for events 5 and 6, etc.

Numerals standing after letters on progress charts indicate the time intervals (in months, weeks, days, or hour) between two events.

Prior to drawing up a progress chart it will be necessary to compile a list of jobs and events. First starting and finishing events and then intermediate ones are to be determined. In the action, it is essential to state the jobs to be completed before starting the given job and the jobs to be carried out simultaneously.

An essential element of any progress chart is the so-called critical path that is composed of a continuous progress of jobs included in the chart from the starting to the finishing events. The total time required for executing the jobs on the criti-

* In complicated progress charts there may also be used, apart from circles, other symbols, such as triangles, squares, rectangles.

cal path, that is shown by solid lines on Fig. 8, is the total time required to reach the end of the contract.

Event 1 on Fig. 8, for example, may mean that the raceways are ready to receive wires, or that the wiring operation may be started; event 13 may indicate that electric wiring has been tested and accepted, that is, the wiring operation in a certain installation region is completed.

On large sites progress charts may be compiled for separate operations or for separate installation regions.

Such local progress charts are combined into a common coordinated progress chart for electrical work on a site.

Progress charts are widely used in practice as they constitute one of the basic elements of modern organization of electrical work and are most useful when installation and wiring operations are carried out by industrialized methods.

2.2. Industrialized Electrical Work

One of the essential trends in the electrical installation practice is the use of industrialized methods, which means that most hard and labour-consuming installation and assembly operations are made at specialized factories and depots.

Industrialized methods permit making most electrical operations independent of the condition and readiness of building and special-purpose jobs. When industrialized methods are used, conduits are laid in foundations, through passages and raceways for electric wiring are made, embedded parts are installed, and many other associated jobs done in the course of building. While these jobs are in progress, the respective electrical equipment is set up, large blocks of busways and wiring systems are completed, power and switchgear cubicles are assembled and the like operations are carried out at the factories.

Such a time coincidence of building and electrical work gives a number of technical and economic advantages, such as:

- (a) cuts down the time of electrical work;
- (b) makes it possible to utilize more efficiently hoisting and haulage mechanisms, tools, and accessories;
- (c) releases personnel from hard jobs that are made at factories under more suitable conditions;
- (d) enables one to fully utilize material resources of the electrical installation contractor and its subordinates;
- (e) considerably cuts down the cost of electrical work.

The main industrialized method is the use of large prefabricated blocks, which gives a great economic effect. For example, a prefabricated metalclad switchgear installation or unit transformer substation for power supply of an industrial shop makes it possible to dispense with special buildings for them, and also to dispense with the inspection, debugging and testing of electrical equipment of these installations.

Items delivered to the installation site are as follows:

(a) unit-type arrangements are carried by special transport facilities and handled by hoisting mechanisms of appropriate capacity to erect them in ready premises or on ready foundations;

(b) large switchboards and control consoles are delivered with instruments and devices removed. The instruments and devices are mounted after the switchboard or control console is installed on site and secured in position so as to prevent any possible damage to them;

(c) outdoor metalclad switchgear cubicles are delivered together with an overhead lead-in, with bushing insulators of the latter removed or suitably protected.

Collecting and secondary switching busbars are usually removed at the factory and arrive at the installation site stowed away in separate packing containers. All the parts and assemblies supplied as standard equipment of metalclad switchgear are marked at the factory according to the delivery list. Contacting surfaces of collecting busbars are coated at the factory by special protective compounds that prevent their oxidation. Hence, these surfaces are not to be finished on site of installation.

All that is needed to install such unit-type arrangements is usually to unpack and mount the parts that have been removed for the period of transportation and to connect supply and outgoing lines to the arrangement.

Industrialized methods are also used in wiring shop's electric circuits, such as busducts.

Prefabricated and suitably marked busbar sections of appropriate design and cross-sectional area are delivered to the industrial shop wherein they are attached to supporting structures and interconnected or connected to the busbar sections of outgoing lines.

Another industrialized method of electrical work consists in completing large-block constructions, assembly parts, electric wiring systems, and miscellaneous components at preassembly divisions. Items delivered from preassembly divisions are ready for installation and do not require additional labour for their assembly, painting, marking, etc.

A preassembly division of a large electrical installation board comprises:

(a) *a work preparation team* engaged in studying design documents, checking reference drawings for compliance with adopted industrial technology, comparing the building and technological drawings with actual work done, compiling the lists of missing embedded parts, planning the dates of starting and completing the electrical work, supervising over the work in progress, drawing up orders for materials and mechanisms required, etc.;

(b) *a completing and production supply team* that functions to complete pieces of equipment and materials, to check parts made and supplied by the preassembly division for quality and for missing items, to accept equipment and materials from the Customer, etc.;

(c) *an executive team* including workmen of the preassembly division preparatory and assembly shops engaged in manufacturing and completing pipelines, busways, and miscellaneous structures, machining sectional and sheet metals, manufacturing catenary wiring systems and trolley lines, assembling and outfitting suspen-

sion and anchor supporting structures, manufacturing supporting cable constructions, etc.

Parts produced by the preassembly division are tested and accepted by a quality control foreman or a specially assigned inspector. These parts are issued with appropriate reports and certificates.

2.3. Mechanized Equipment Used for Electrical Work

Special-purpose mechanisms and power-operated tools are used to reduce manual labour to the minimum.

2.3.1. Mechanisms for Treatment and Preparation of Wires

One of the most labour-consuming processes in electrical work is the preparation of electric wires that involves a great number of minute manual operations:

- (a) measuring the wires and cutting them to desired lengths;
- (b) stripping insulation from the ends of conductors or cables and finishing bare leads for connection, tapping, and for joining with lights and circuit-opening devices;
- (c) setting up a circuit, its testing, and marking the conductor leads by means of PVC caps, sleeves, or bands that are red-coloured for phase leads, blue-coloured for a vacant lead running from a switch to a light, and white-coloured for a neutral lead;
- (d) connecting and tapping off the conductors of cables and wires by compression, soldering, or welding;
- (e) insulating bare portions of soldered or otherwise made joints of interconnected or tapped off sections of conductors;
- (f) removing set-up wiring systems from stands or benches, coiling them, applying tags to coils to identify the type of wiring, stowing the wiring away in containers for shipment to the installation site.

With mechanized preassembly, all these jobs are executed on a process line (Fig. 9). A coil of wire of the respective cross-sectional area is mounted on a drum 1 of a laying-out table (Fig. 9a). The loose end of the wire is to be attached to the supporting board 5 of a measurement stick 4, the post 3 is to be displaced through the required distance, checked against the straightedge and fixed in position by means of a screw clamp. A definite amount of wire is to be wound manually on the post 3 and supporting board 5, whereupon the wire is cut to desired lengths by means of lever shears 2. These lengths are then removed from the table and suspended from the hooks of a mobile rack (Fig. 9b). The hooks are provided with frames to receive tags indicating the size of wire lengths.

The rack with wire lengths is delivered to a bench (Fig. 9c), whereon they are further treated (the interconductor film is cut away, insulation is stripped off the conductors, etc.). Conductors are stranded and separate wire lengths are welded together to form a complete assembly on a stand (Fig. 9d).

The type MP-1, MC-2, and C3-3 mechanisms forming a process line for treating wires are used where most jobs are associated with wiring the lighting systems.

The MP-1 mechanism (Fig. 10a) functions to cut wires of up to 6 mm^2 in sectional area of all types into desired lengths and to automatically count the lengths cut.

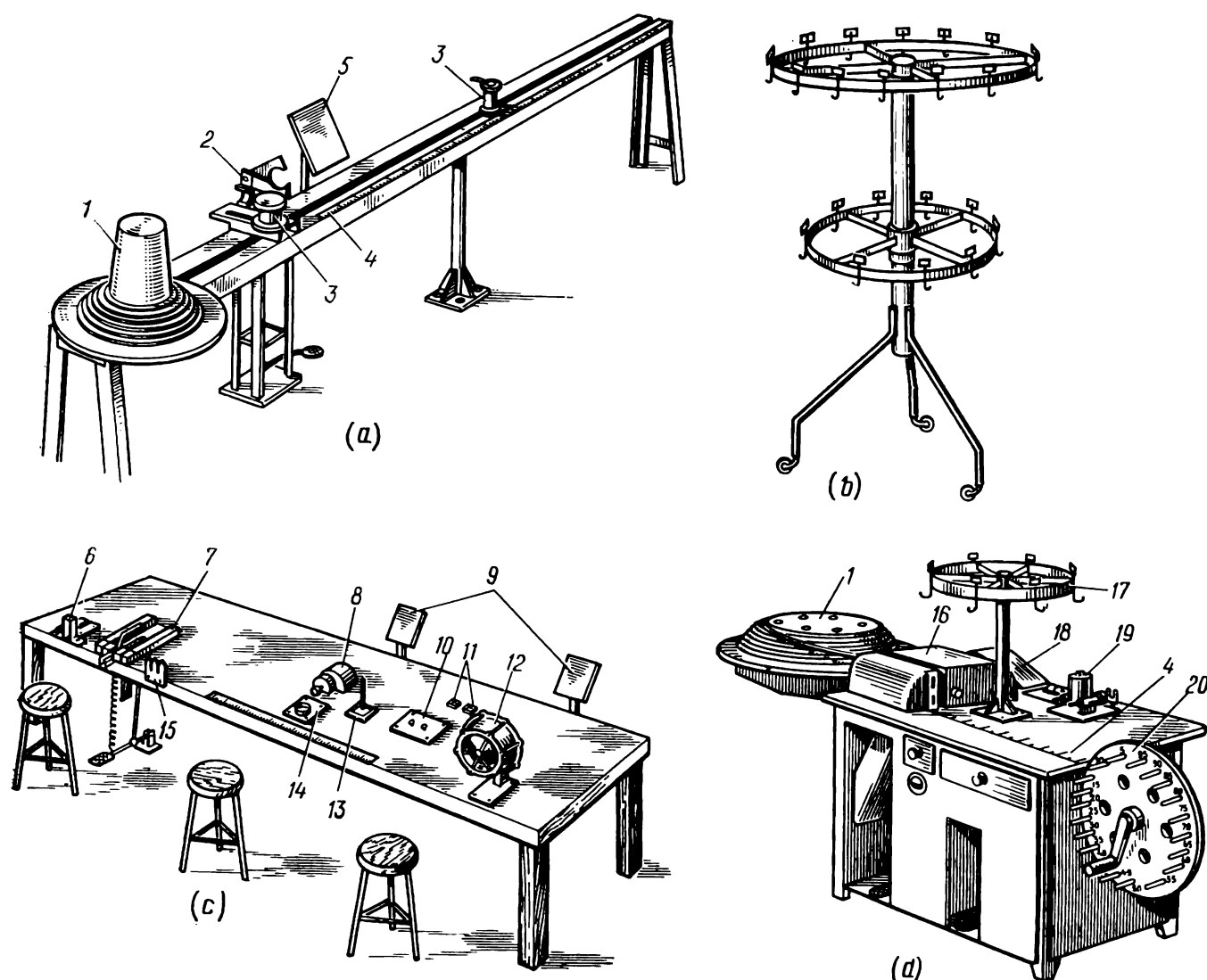


Fig. 9. Basic elements of a mechanized process line for treating wires and preassembling wiring elements

a—laying-out table; *b*—mobile rack (store); *c*—bench; *d*—stand for treating wires and preparing wiring assemblies; 1—drums for mounting wires being unreeled; 2—lever shears; 3—movable posts; 4—measuring sticks; 5—supporting board; 6—foot-operated shears; 7—foot-operated fixture for wire skinning; 8—wire strander; 9—drawing board; 10—circuit tester; 11—paint baths for marking wire leads; 12—drum for coiling ready wire lengths; 13—manual drill for making holes in boxes; 14—jig fixing the boxes when drilling holes in them; 15—manual wire stripper; 16—power-operated cutter for wires, films, and insulation stripping; 17—table-mounted rack; 18—wire strander; 19—wire welder; 20—measuring drum

The mechanism consists of a take-off drum, wire dresser, wire cutter, and programming unit.

The mechanism operates as follows. A coil of wire is fitted on the take-off drum inserted within a frame. The end of the wire is passed between the rollers of the wire dresser and cutter. The desired program (wire length and number of lengths)

is set on the programming unit. The mechanism is thrown in operation by pushing the start button. After the desired number of wire lengths are cut, the mechanism automatically stops running.

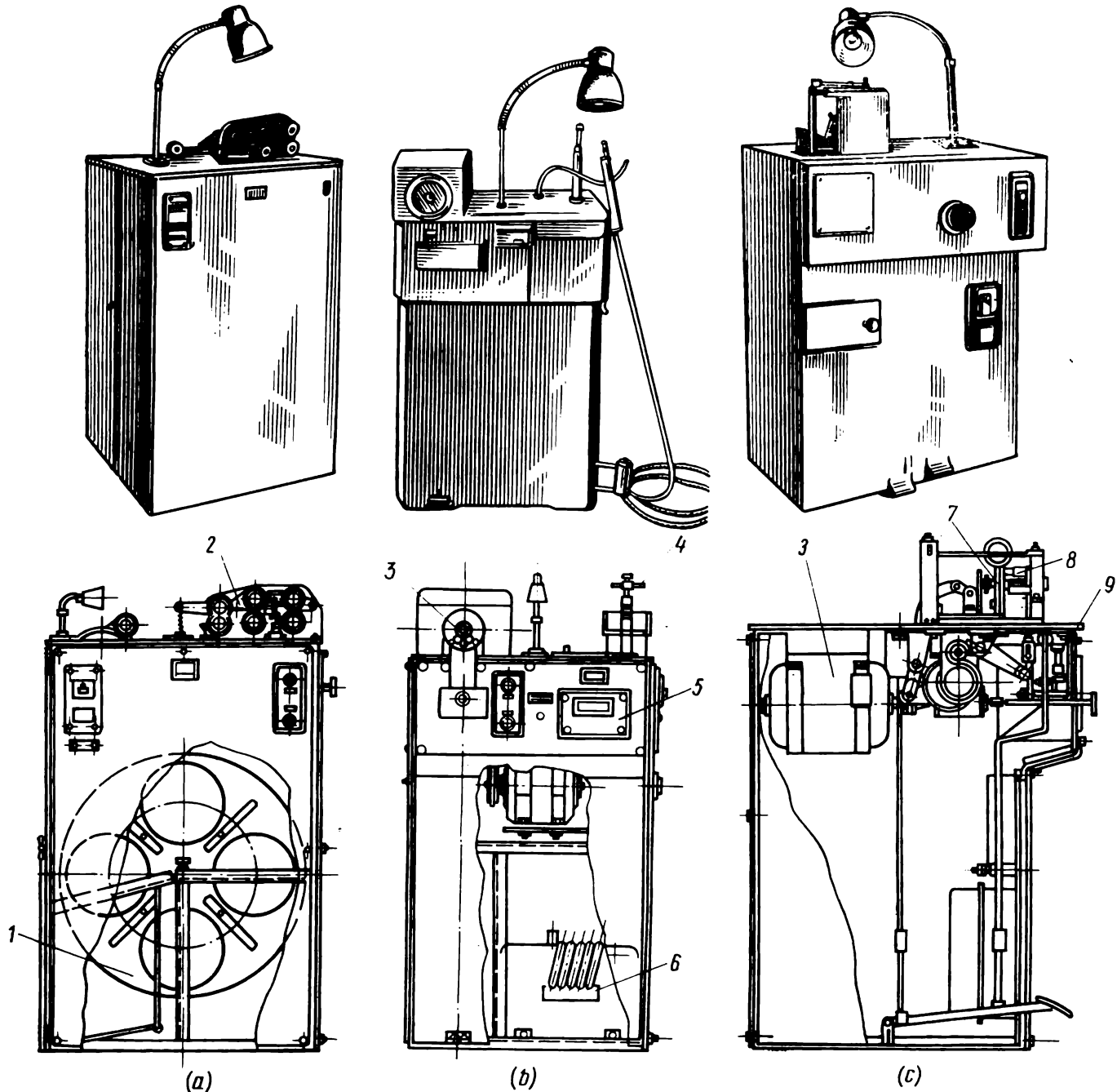


Fig. 10. KMO-3 set for mechanized treatment of wires up to 10 mm^2 in cross-sectional area
 a—MP-1 mechanism; b—C3-3 mechanism; c—MC-2 mechanism; 1—drum; 2—dresser; 3—electric motor; 4—
 head; 5—wire looping device; 6—drive pedal; 7—stranding head; 8—carbon electrode; 9—test desk

The C3-3 mechanism (Fig. 10b) is used to strand wires, trim them at the ends, weld and check the prepared wire lengths. The cross-sectional areas of wires treated shall be maximum 6 mm^2 .

The common frame of the mechanism mounts a wire stranding and trimming head, a wire welder (the welder is furnished complete with manual tongs for clamping the strands being welded, an electrode holder with a carbon electrode, and a type TC-2000 welding transformer), and a test desk with a pilot lamp.

The head functions as follows. Pushing the start button throws the drive in operation. Bare wire leads to be stranded are assembled in bundles and inserted into the head throat as far as they go, whereupon the pedal is pushed. The jaws catch the bundle and strand it. Upon the completion of this operation the pedal is released.

For trimming, the stranded conductor is inserted in one of the bottom holes of the head as far as it will go, whereupon the pedal is pushed.

For welding the strands, the welding transformer packet switch is turned on to supply voltage to the pliers and the electrode holder. The strands are clamped by the tongs and welded together by means of the carbon electrode.

The stranded and welded conductor is checked for correct stranding and absence of break. For this, the ends of the conductor are brought in contact with two terminals on the test desk. The pilot lamp must come on if the conductor is stranded properly and not a single strand is broken.

The MC-2 mechanism (Fig. 10c) is used to strip insulation off the leads of single- and double-strand wires, up to 10 mm^2 in sectional area, and to loop the ends of wires, up to 4 mm^2 in sectional area. Insulation is stripped over a length of 15 to 45 mm. The inner diameter of loops is from 3.2 to 6.2 mm to receive binding posts, 3, 4, 5, and 6 mm in diameter.

The mechanism consists of a stripping head and a looping device.

The head is actuated by an electric drive and a cam gear mounted on a frame. The MC-2 mechanism operates as follows. Pushing the start button starts the drive motor. The wire end is inserted in the intake port of the head as far as it will go. This done, the left-hand pedal is pushed to start the mechanism.

After the insulation is stripped the mechanism stops automatically.

The wire end to be looped is placed on the looping device between the appropriate mandrel and the pin. The looping device is actuated by levers set in motion by pushing the right-hand pedal. After the loop is finished, the mandrel goes down automatically and the loop can be easily removed.

Any of the mechanisms illustrated by Fig. 10 can likewise be used separately. All the three mechanisms can be assembled to form a semi-automatic line, KMO-3 (set of treating mechanisms) and used in prefabrication workshops. The set of mechanisms is designed to treat wires up to 10 mm^2 in cross-sectional area.

In wiring power systems with conductors of 16 mm^2 and larger sectional areas, use is made of a KMB-4 set of mechanisms assembled of two mechanisms, MPB and MCB, forming a process line and also used for bench preparation of wires, 16 to 240 mm^2 in cross-sectional area.

The MPB mechanism (Fig. 11a) is used for cutting wires of large sectional areas to the desired lengths. It is fitted with guide rollers 3 and 4, a metering device 5 with a counter, rollers 6, a wire cutting mechanism 8 with knives, a reduction unit 9, and a transmission box 10 that functions to transmit rotational motion to drawing rollers and a winding drum 11. The wire cutting mechanism with knives is

driven by an electric motor 2, while the drawing rollers and the winding drum are set in motion by a motor 1. The drum carrying wire is placed on the left-hand side of the mechanism. The wire is first passed over guide rollers 3 and 4 and drawn into the mouth 7 in front of the winding drum by means of drawing rollers 6. The wire

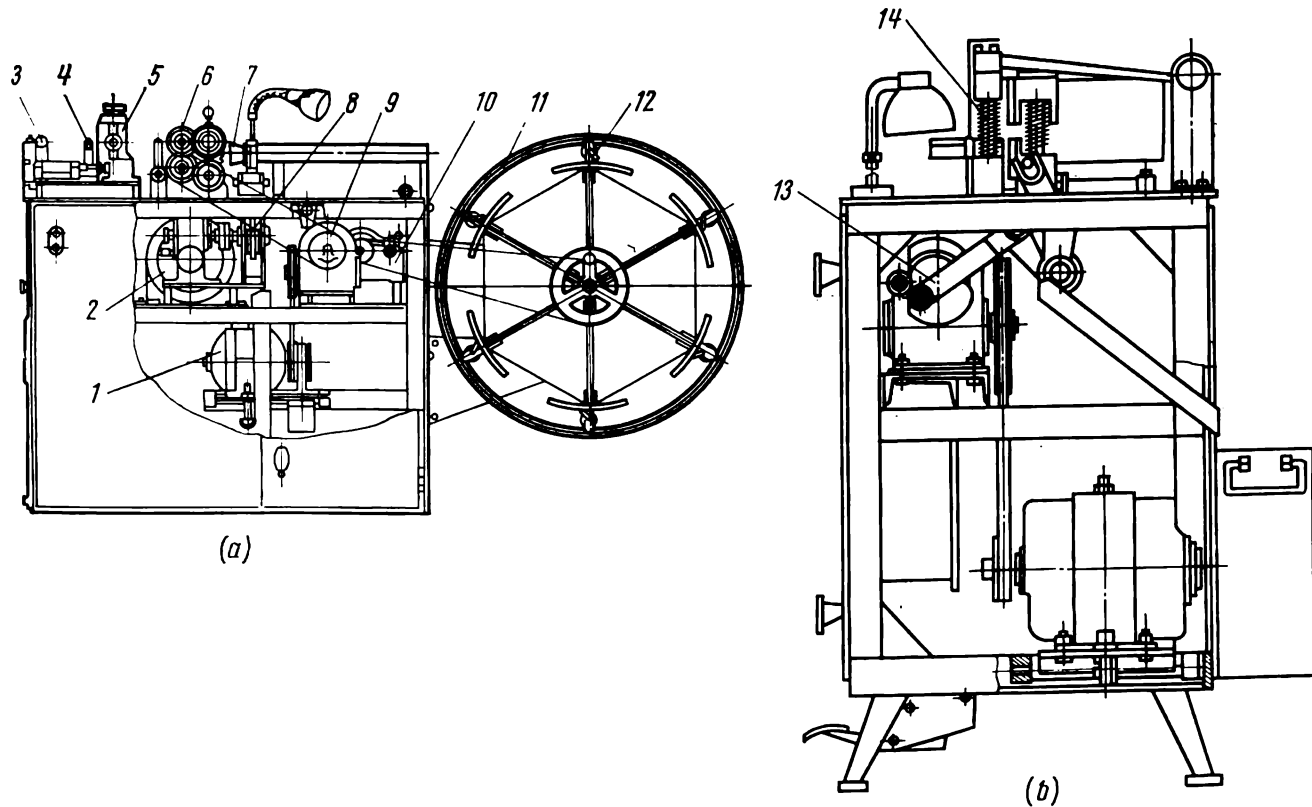


Fig. 11. KMB-4 set for treatment of wires from 16 to 240 mm² in cross-sectional area

a—MPB wire cutting mechanism; *b*—MCB wire skinning mechanism; 1—winding drum motor; 2—wire cutting mechanism motor; 3, 4—guide rollers; 5—metering device with counter; 6—drawing rollers; 7—mouth; 8—wire cutting mechanism with knives; 9—reduction unit; 10—transmission box; 11—winding drum; 12—clamp securing the wire on the drum; 13—cam-and-lever transmission; 14—insulation stripper

end is secured on the drum in a clamp 12, whereupon the mechanism is thrown in operation by switching on the motors. The desired (program-controlled) wire length is cut automatically.

The MCB mechanism (Fig. 11b) is used to skin the IIP and AIIP wires of large cross-sectional areas. The electric drive and the cam-and-lever transmission 13 are accommodated within the frame; the wire skinning unit 14 is mounted on the external plate. Insulation can be stripped over different lengths depending on size and type of lugs. The MCB mechanism operates at a rate of 20 cycles per minute.

The above-described process lines for preparing wire lengths are most simple in construction and have found wide application on installation sites. There are also more intricate process lines for industrialized electrical work, such as for wiring busways, for concealed wiring in gas pipes.

2.3.2. Electrician's Mechanisms

Installation of electrical equipment often involves a great amount of labour-consuming work, such as making seats for concealed wiring fittings, drilling channels and through holes in walls and intermediate floors, drawing wires into tubes and conduits, connecting conductors, etc. All these jobs shall be carried out with the aid of power-operated tools and machines.

Drilling operations are made by means of motor- or air-driven tools furnished with drills and bits clad with hard alloys. Motor-driven tools and machines are available for operation on 220-V commercial-frequency and 36-V, 200-Hz supply. The latter are supplied with power through a frequency changer.

Double-insulation motor-driven tools have found wide application in electrical work. Such tools are noted for high electric strength of their winding insulation. Hence, their non-current-carrying parts remain dead throughout the entire running period and danger of electric shock is excluded.

Air-operated tools are physically reliable, ensure safety in operation and are rather light in mass (4 to 6 kg). However, they are not so extensively used on installation sites as they need compressors and pipings to pass compressed air to them.

Channel-cutting tools are the examples of motor-driven cutting tools.

Channel-cutting tools are built around motor-driven tools (primarily, electric drills) driven by an a.c. motor operating at a commercial (50 Hz) or high (200 Hz) frequency.

A *channel-cutting tool* (Fig. 12a, b) consists of an electric motor 3 connected through a flexible cord 7 to 36- or 220-V supply mains, a face-and-side cutter 5 reinforced by grade BK-6 or BK-8 hard alloy, grips 1, and guide

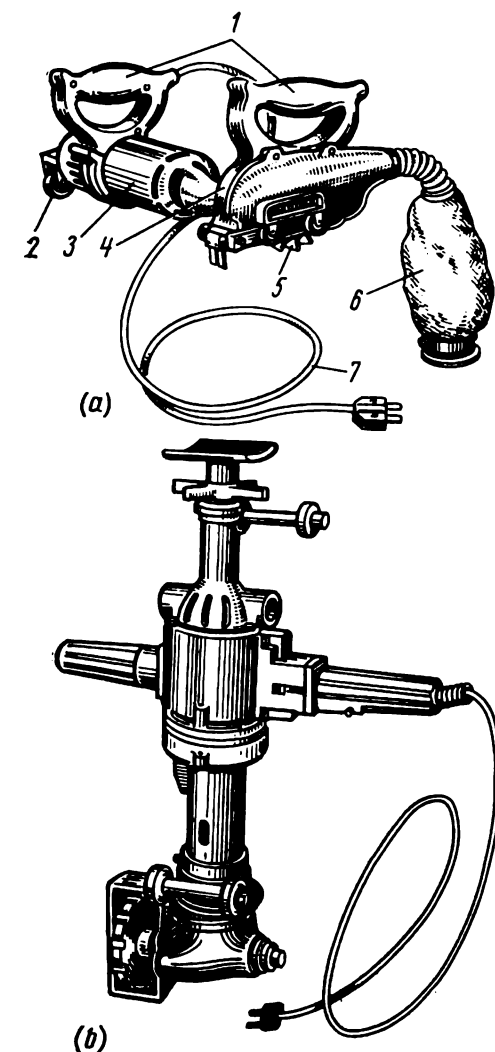


Fig. 12. Channel-cutting tools

a—horizontal; b—vertical; 1—grips; 2—guide roller; 3—motor; 4—body; 5—face-and-side cutter; 6—dust collector; 7—flexible cord

rollers 2 that serve to facilitate handling the tool when moved over the surface being treated and to afford the desired cutting depth. The channel-cutting tools make it possible to obtain channels and grooves as large as 10 mm wide and 20 mm deep. If larger channels are required, the channel-cutting tools are used to cut two parallel grooves whereupon the material between them is removed by a slotting tool.

The channel-cutting tool runs at a rate of 3 or 5 m/min depending on the material of the building component (brick, concrete, etc.).

Routing conductors in pipes involves such operations as bending, cutting, and the like treatment of a great number of steel pipes and drawing wires into them by means of power-operated tools.

The *TPT-24 pipe bender* (Fig. 13a) is a manual tool used to bend thin-walled pipes, 18 and 24 mm in diameter. It consists of a cast-iron plate 7 mounting pins

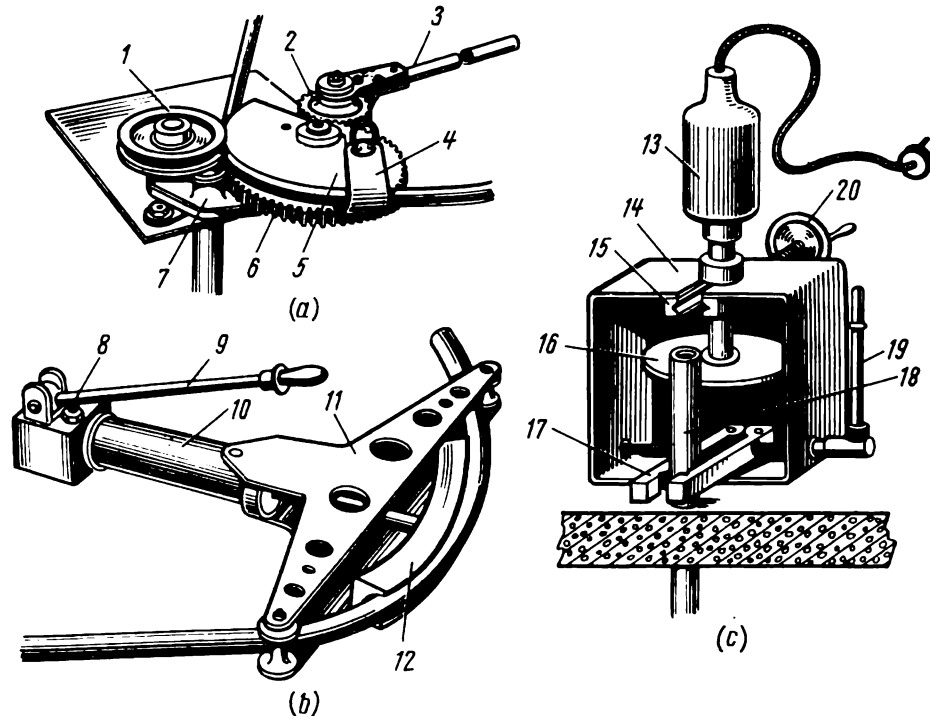


Fig. 13. Pipe treatment mechanisms

a—TPT-24 manual pipe bender; b—hydraulic pipe bender; c—MTΦ-2 pipe trimmer; 1—roller; 2—small gear; 3—lever; 4—clamp; 5—groove quadrant; 6—large gear; 7—plate; 8—hydraulic pump; 9—actuating lever; 10—hydraulic press; 11—head with changeable rollers; 12—quadrant; 13—motor-driven grinder; 14—housing; 15—wheel carriage; 16—grinding wheel; 17—clamping device; 18—pipe; 19—grip; 20—handwheel

that carry a large gear 6 with a groove quadrant 5 and a small gear 2. The small groove is rotated by rocking a lever 3 fitted with a ratchet gear. A roller 1 is adjacent to the groove quadrant.

The pipe to be bent is placed between the groove quadrant and the roller, secured in position by a clamp 4 and bent through the desired angle by rocking the lever 3. The TPT-24 pipe bender is useful where a small number of pipes are to be bent. On installation sites where many pipes are to be bent use is made of hydraulic pipe benders.

A *hydraulic pipe bender* (Fig. 13b) consists of a hydraulic pump 8 with an actuating lever 9, a hydraulic press 10 fitted with a head 11 that has changeable rollers and a changeable quadrant 12.

The pipe to be bent is placed between the rollers of the head 11 and the quadrant 12, whereupon the lever 9 is rocked to pump oil into the hydraulic press ram.

In the action, the operating plunger carrying the quadrant at the end starts moving and bends the pipe.

There are many types of hydraulic pipe benders, most popular being the TTP-3/4 type for bending pipes of up to 20 mm in diameter and the type PTF-2 benders for pipes of up to 50 mm in diameter.

The MTΦ-2 pipe trimmer (Fig. 13c) is used to trim the excess portion of pipesutting beyond intermediate floors, foundations, and miscellaneous building structures. Trimming may be found necessary where prefabricated pipes do not suit the dimensions of a building.

This tool consists of a motor-driven grinder 13 and a housing 14 accommodating a screw-feed wheel carriage 15, a grinding wheel 16, and a clamping device 17 that holds the pipe section being trimmed.

The pipe 18 is held in position between the jaws of the clamping device by means of a screw with a grip 19 furnished with a ratchet mechanism. Due to the ratchet mechanism the grip can be turned without rotating about its axis through 65 to 70 deg. either side in turn when clamping a pipe. A handwheel 20 with a grip is provided to feed the wheel carriage and to carry it away from the pipe.

The IIPT draw-in mechanism (Fig. 14a) is designed to pull conductors into pipes of 20 to 50 mm in diameter. It consists of a steel housing 1 accommodating the draw-in device, jaws 2 mounted on the front wall of the housing and used for clamping the mechanism on the pipe, and a handle 7.

The pipe to receive a conductor is placed between the mechanism jaws 2 and secured therein with a screw 3. Screws 4 are turned to adjust the desired clearance between the rollers accommodated within the housing and then a piece of wire is inserted into the housing through a bush in its rear wall and clamped by screws 4. Turning the handle 7 drives the wire into the pipe until it emerges on the opposite end of the pipe. The conductor to be drawn in is connected to the wire end and the handle is rotated in the opposite direction until the wire leaves the pipe.

To speed up this operation, the handle 7 can be inserted in the seat 6. This is possible when the pipes are short and straight.

The mechanism mass is about 7 kg, and therefore it can be easily carried by means of the strap and suspended in working position through an eyebolt 5.

The II MT mechanism (Fig. 14b) is used to draw conductors of large sectional areas into pipes. It is furnished with a drive motor and consists of an electric drive 8, a housing 1 accommodating the draw-in device, and a telescopic tripod 9 supporting the mechanism in operation. The mechanism mass is about 25 kg.

The auxiliary wire is pushed into the pipe and pulled out by means of rollers actuated by an electric motor.

The mechanical design and principle of operation of the II MT mechanism are similar to those of the II PT mechanism described above. The II MT mechanism is fitted with a roller-type deflection system 10 that functions to draw conductors into pipes through draw-in boxes.

Manual and motor-operated hydraulic and mechanical presses are used for connecting conductors over 50 mm² area in troughs and for terminating them with lugs. Most popular are manual hydraulic presses II TP-20, P TP-7M, manual mechanical presses PM TP-7M, and motor-operated hydraulic presses II TP TP-2.

Manual hydraulic presses of all the types are pressure afforded by a hand-operated pump mounted on the press body. Working fluid is grade AK-10 pure oil or grade C machine oil introduced into the press cylinder (body).

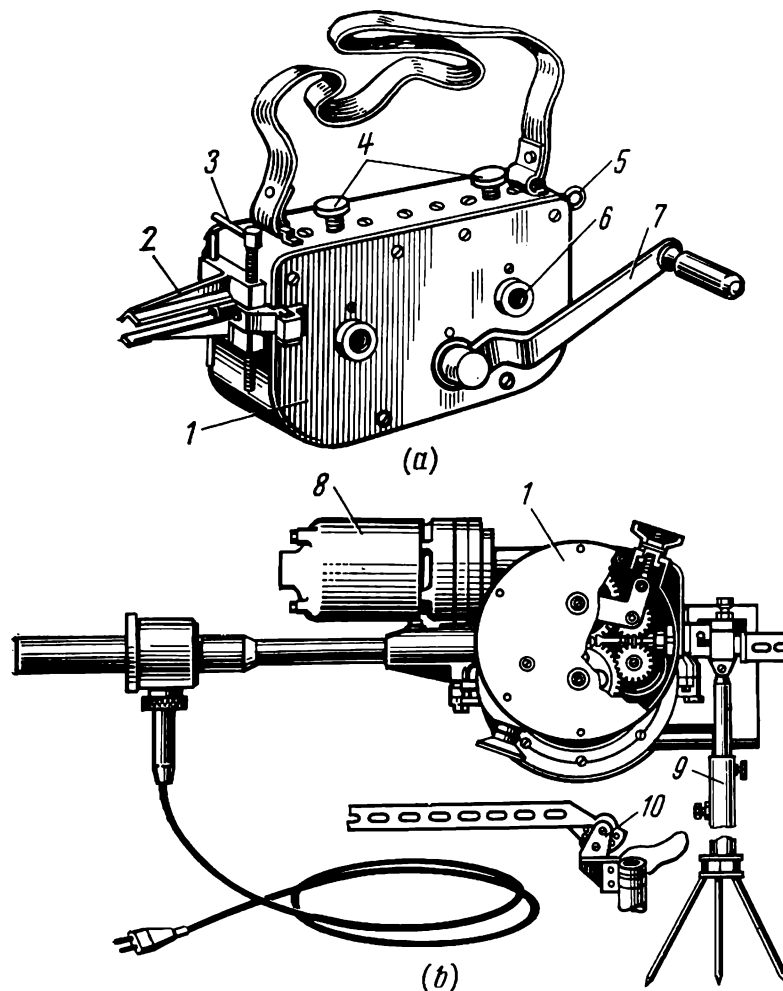


Fig. 14. Draw-in mechanism

a—ППТ; b—ПМТ; 1—housing; 2—jaws; 3—screw for fixing the jaws on pipe; 4—adjusting screws; 5—eyebolt; 6—seat; 7—handle; 8—electric drive; 9—telescopic tripod; 10—roller-type deflection system

The ППР-20 manual hydraulic press (Fig. 15a) consists of a clamp 1 to receive changeable punches and dies, a cylinder 2, an oil pump 3 with a lever 4, a grip 5, and a strap 6.

The clamp 1 is screwed into the cylinder 2. The punch 7 or the die 8 is inserted in the clamp. The press operates as follows. The part to be compressed (a trough or a lug) is inserted between the punch and the die selected to fit the size of the part, then the lever 4 is moved up and down to actuate the pump. The latter creates the required pressure of working fluid within the cylinder 2. The working fluid pressure is imparted to the punch and the die, with the result that the part placed between them is compressed.

The maximum pressure on the working member of the press is 20 tf. This press is used for the connection and termination by compression of aluminium conductors having a cross-sectional area of 16 to 240 mm². The mass of the press is 5 kg.

The *PII-7M manual hydraulic press* (Fig. 15b) is used to compress copper and aluminium conductors and cable cores. The press consists of a cylinder, a piston

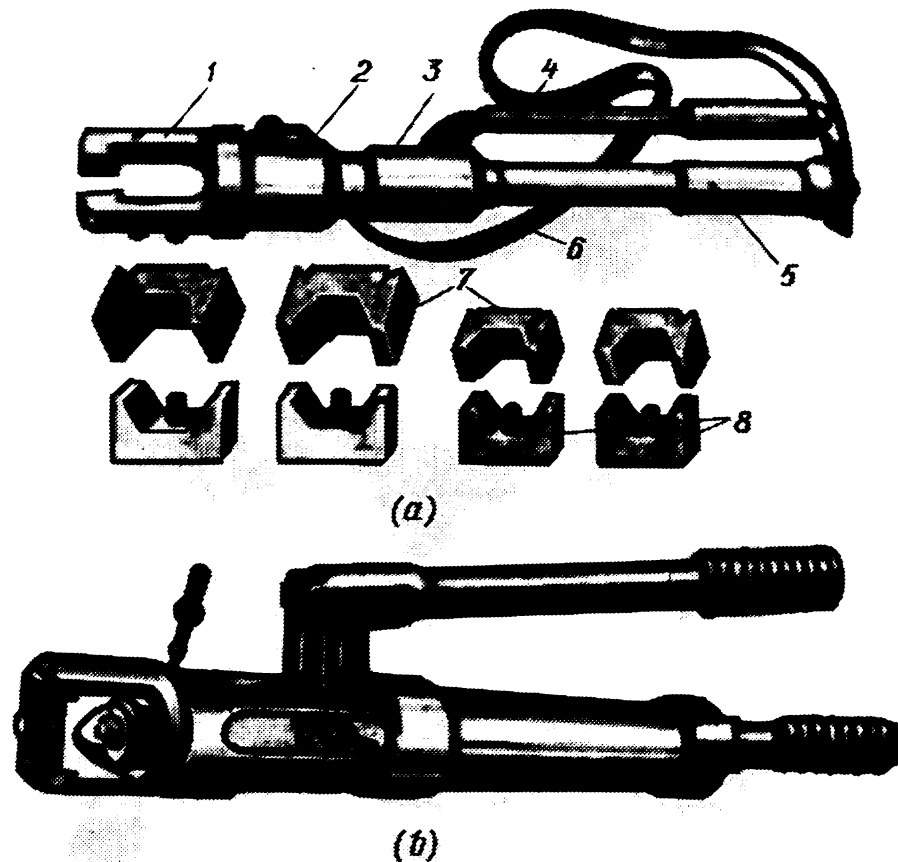


Fig. 15. Wire presses (a, b)

a—manual hydraulic press ПГП-20; b—manual hydraulic press ПГП-7М; c—manual mechanical hydraulic press ПМП-7М; d—motor-operated hydraulic press ПГЭП-2; 1—clamp (working element); 2—body; 3—oil pump; 4—lever; 5—grip; 6—carrying strap; 7—punches; 8—dies; 9—cable drum; 10—working fluid hoses; 11—high-pressure pump; 12—electric motor drive; 13—flexible cord for connecting the motor to supply; 14—press mechanism head; 15—working fluid tank

carrying a punch at its end, and a head receiving a die. This press depends for its operation on the same principle as the ПГП-20 press, the difference being a lighter force created by the piston; this is why the ПГП-7М press is mainly used to compress conductors and cable cores having a cross-sectional area of 16 to 150 mm².

The *ПМП-7М manual mechanical hydraulic press* (Fig. 15c) consists of a clamp 1 (working element) receiving a punch 7 and a die 8, levers 4, two grips 5 (one fixed and the other movable), and a drum 9 with a cable.

The clamp 1 is hinged on the body 2 and can be locked in position. A punch holder is loosely mounted in the central hole of the body. Any manipulation with levers sets in motion the punch holder together with the punch and as soon as the required pressure is set up, the part fitted between the punch and the die is compressed. Compression ceases at the moment the punch and the die meet.

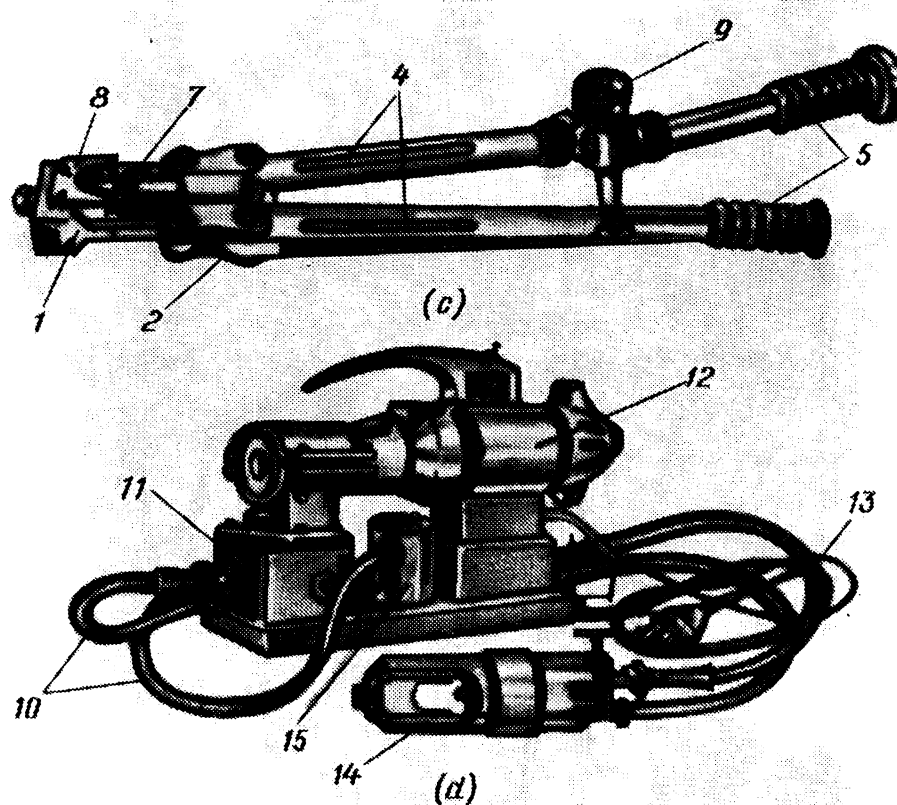


Fig. 15. Wire presses (c, d)

To facilitate operation with levers, the cable drum 9 mounted on the right-hand lever is employed.

The maximum pressure on the working member of the press is 7 tf. This press is used to terminate conductors having a cross-sectional area of 16 to 240 mm². The mass of the press is 5 kg.

The *ПГЭП-2 motor-operated hydraulic press* (Fig. 15d) is used on large installation sites where a great number of large-area conductors and cable cores are to be connected and terminated by compression. This press consists of an electric drive motor 12, a high-pressure pump 11, and a press mechanism head 14. The open portion of the head mounts a punch and a die selected to fit the size of parts to be compressed (troughs, lugs, etc.). The working fluid of the press is pure transformer oil or machine oil. The press is used most efficiently for compressing copper conductors and cable cores having a cross-sectional area of 70 mm² and larger still because

these jobs involve much labour and time when carried out by means of other mechanisms.

Electrical work also requires a great number of posts, ladders, and pyrotechnical facilities.

Posts and ladders (Fig. 16a, b, c) are furnished with mounts to receive a gun or a power-driven tool and are used where fastening joints are to be made or holes

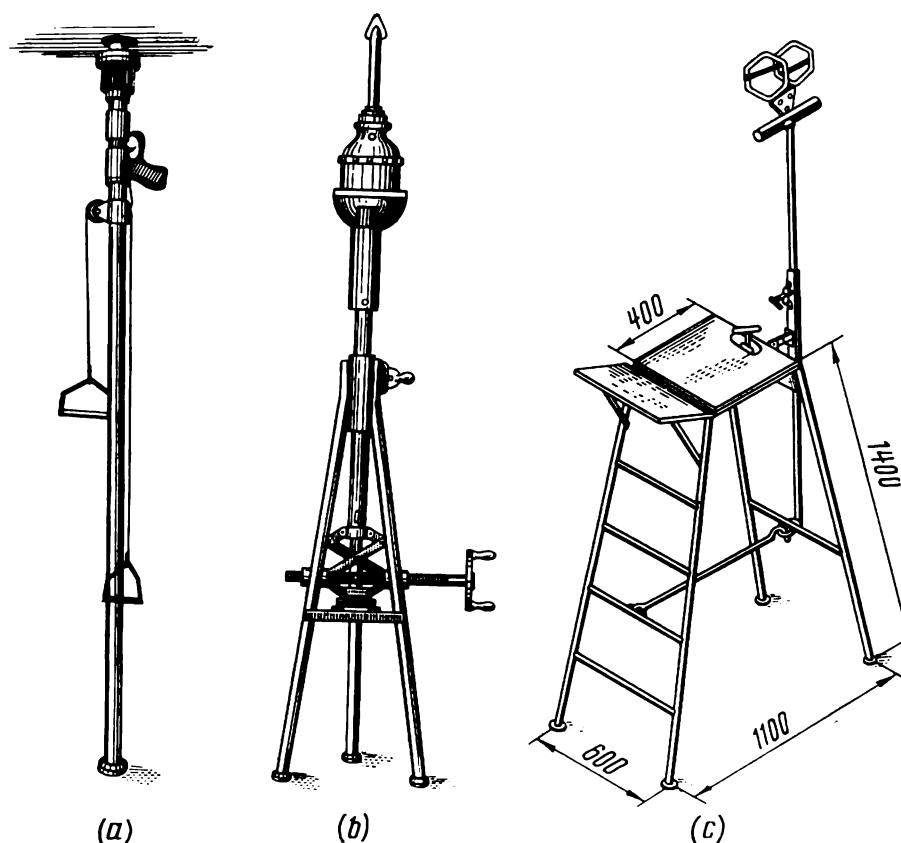


Fig. 16. Handling facilities

a—gun post; b—motor-operated tool tripod; c—ladder with board to support electrician's tools

drilled at a considerable height. The posts and ladders are furnished as standard equipment and are very convenient, since they are collapsible in construction and relatively light in mass, which makes them easy to carry, assemble, and use.

Pyrotechnical facilities (Fig. 17a, b, c) are, essentially, arbours, presses, and pillars actuated by the energy of explosion of powder contained in a cartridge.

Pyrotechnical arbours are used to drive dowels into brick or concrete structural elements of buildings and constructions (walls, intermediate floors, etc.) for fixing electrical hardware and metal elements on them.

Two types of pyrotechnical arbours are in use, viz., a type ОД-6 arbour that is simple in design and a type ОДП-4М pyrotechnical dowel arbour of a more advanced construction.

The ОДП-4М pyrotechnical arbour (Fig. 17a) consists of a steel head 1 receiving the top threaded end of a charging rod 3 accommodated within a steel case 4 that is closed with a threaded cap 2. The steel case houses a piston 5, a dowel 6, and a cartridge 11. The case is protected with a steel cowl 8 covered with rubber 10. The case is protected with a steel cowl 8 covered with rubber 10.

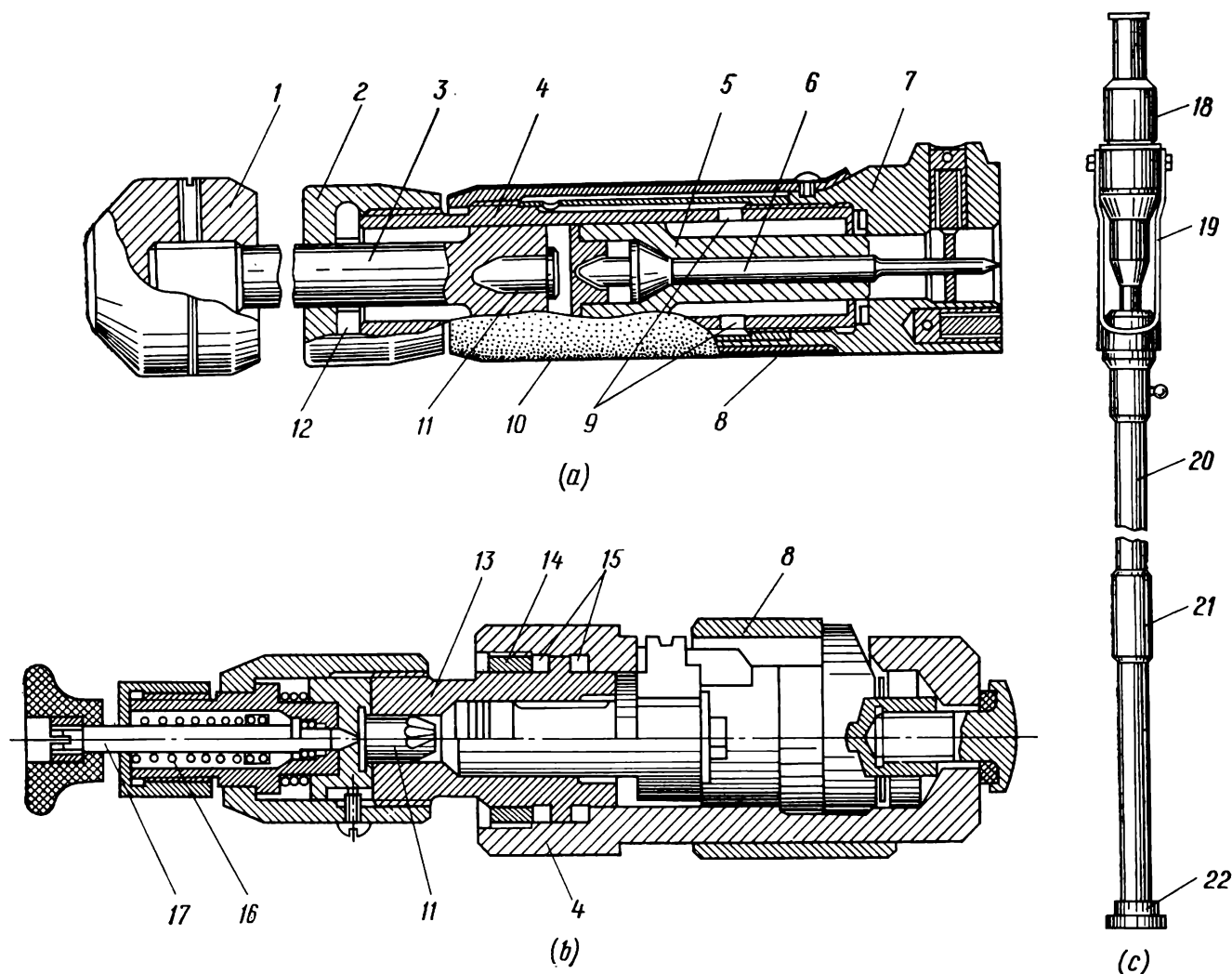


Fig. 17. Pyrotechnical facilities

a—arbour ОДП-4М; b—press ППО-95; c—pillar УК-2М; 1—head; 2—cap; 3—charging rod; 4—case; 5—piston; 6—dowel; 7—flange; 8—cowl; 9—exhaust holes; 10—rubber cover; 11—cartridge; 12—damping washer; 13—intermediate bush; 14—safety washer; 15—damping ring; 16—striker-and-pin assembly spring; 17—striker; 18—pyrotechnical head; 19—slewing-and-buffer mechanism; 20—rod; 21—sleeve; 22—pillar thrust bearing

The source of energy in the ОДП-4М arbour is a series B (B4 through B9) cartridge meant for use in a type СМП gun.

The ОДП-4М pyrotechnical arbour operates as follows. Striking the head 1 of the charging rod 3 with a hammer breaks the cap of the cartridge 11 thereby igniting the powder charge within the cartridge. In the action, blast gases exert pressure on the piston 5 with the result that the latter starts moving within the case, pushes the dowel 6 without acceleration and drives it into the structural ele-

ment. With a post-shot movement of the piston, exhaust holes 9 open and discharge blast gases into the atmosphere. The piston rebound is suppressed by a damping washer 12.

The ОДП-4М commercial arbours have the following specifications: about 30 shots per hour; maximum 3,400 to 3,600 shots (4,800 to 5,000 shots when spare items are used); length is 204 mm; diameter is 52 mm; mass is about 2 kg.

The ППО-95 pyrotechnical press (Fig. 17b) also depends for its operation on the energy of powder charge explosion and is used to terminate single-strand aluminium conductors having a cross-sectional area of 35, 50, 70, or 95 mm² by making a contacting surface with a hole at the end of the conductor that is then bolted to the busbars and devices.

The ППО-95 press uses series B7 cartridges only. The press makes it possible to terminate aluminium conductors with about 40 lugs per hour thereby releasing the installation personnel from tedious and time-consuming work.

The press is a portable tool weighing 2.5 kg. Its mass together with standard items (punches, dies) and case is about 8 kg.

The УК-2М pyrotechnical pillar (Fig. 17c) is used to drill holes in ferroconcrete intermediate floors of buildings and structures. It consists of a pyrotechnical head 18, a slewing-and-buffer mechanism 19, a rod 20 with a sleeve 21, and a thrust bearing 22. The head is secured within the slewing-and-buffer mechanism and the latter is fitted on the rod mounted on the thrust bearing.

The pillar is simple in construction, has a reliable percussive and-triggering mechanism and an interlocking device that makes accidental shots impossible.

The pillar is set in action as follows: a series B or Г cartridge meant for use in a type CMII gun is inserted in the gun chamber accommodated in the barrel of the pyrotechnical head along with the drift and the piston. The barrel communicates with the body housing the percussive-and-triggering mechanism. Pushing the percussive-and-triggering mechanism makes a shot with the result that the blast gases force the piston to push the drift out of the barrel, thereby piercing a hole in the building component. The drift is of a conical shape so that it is efficiently self-stopped in the pierced hole. The drift motion is also limited by a special buffer provided in the barrel.

The pyrotechnical pillar is convenient and safe in operation, does not need ear muffs in operation and is furnished with a recoil buffer.

Specifications of УК-2М pillar

Shots per hour	about 30
Maximum number of shots with the use of spare parts	not over 5,000
Maximum diameter of hole pierced in a concrete wall, 40 mm thick, mm	35 to 40
Total length of pillar, mm	1,800
Mass, kg	8

A single-charge gun CMII-3М is also used in electrical work practice.

The CMII-3М gun (Fig. 18a, b) consists of a multipurpose safety cap 1, an interlock sleeve 10 accommodating the gun barrel, a barrel sleeve 2, and a grip.

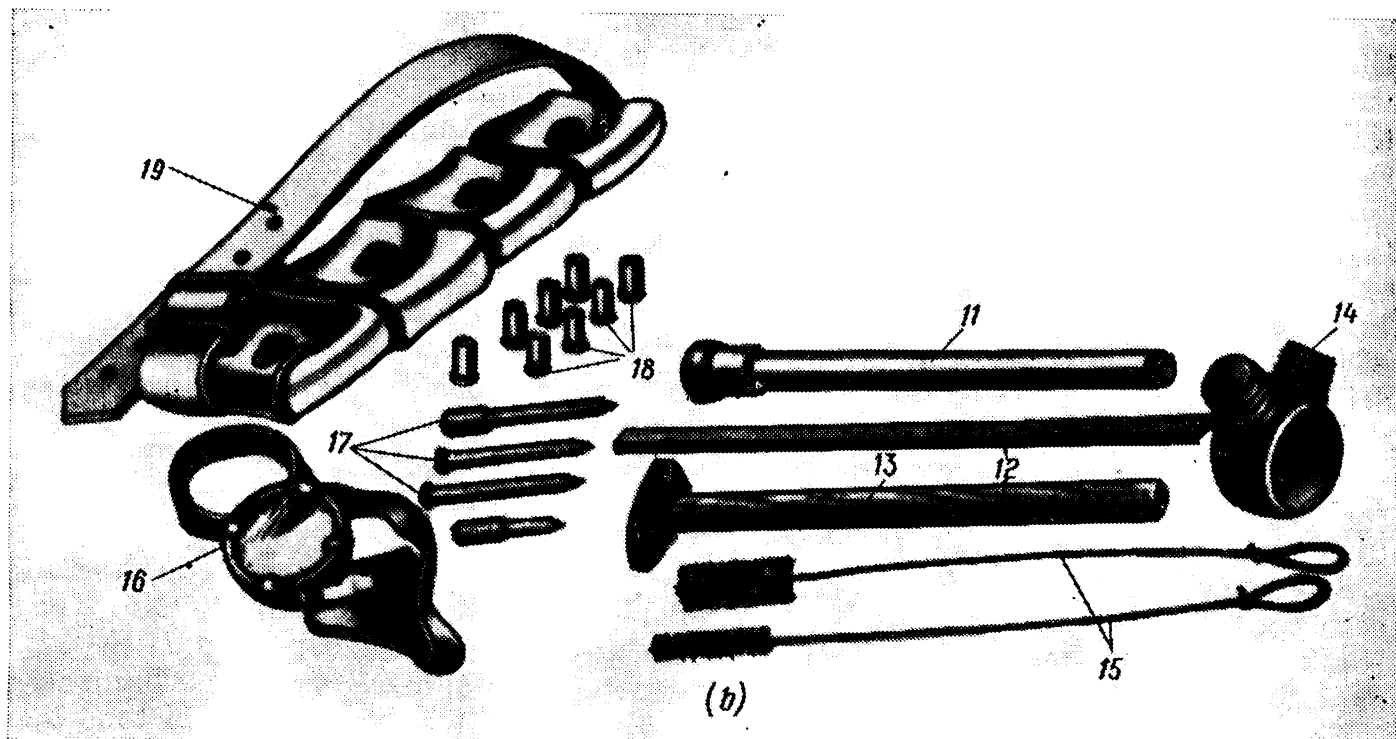
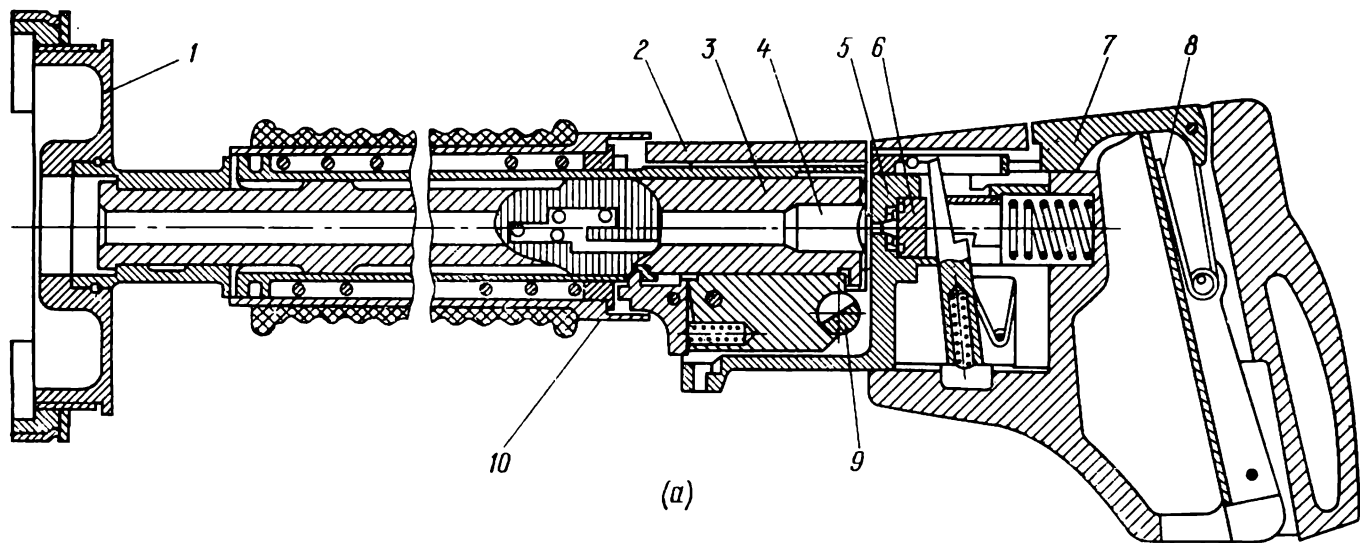


Fig. 18. CMII-3M gun

a—sectional view; b—gun accessories: 1—multipurpose cap; 2—barrel sleeve; 3—barrel; 4—cartridge chamber; 5—reset spring; 6—striker; 7—safety device; 8—lever; 9—locking pin; 10—interlock sleeve; 11—bore 8 changeable barrel; 12—ram; 13—hammer; 14—lubricating fitting; 15—barrel cleaning brushes; 16—goggles; 17—dowels; 18—cartridges; 19—cartridge belt

The gun is furnished with three barrels, two of bore 8 and one of bore 12. One of the bore 8 barrels has a long cartridge chamber similar to that of the bore 12 barrel, which makes it possible to use this barrel with group "T" cartridges noted for a heavy charge of powder and, hence, a high shooting power.

The CMII-3M gun is used for driving fastenings, such as dowel nails, dowel screws, into concrete or brick bases. It is convenient in operation and its mass does not exceed 4 kg.

The CMII-4M gun has been recently developed for driving fastenings, such as dowels, that can be driven in by guns of all types, and also a special dowel nail that is to be driven into robust concrete structures, grades 500 and 600, containing finely crushed stone. It is distinguished from the CMII-3M type by a longer barrel and a more simple cap, which extends its field of application in installation practice.

The CMII-3M and CMII-4M guns are furnished with multipurpose caps having hairlines to aim the gun barrel at symmetry axes marked on the surface of a building component (wall, partition, etc.).

To make a shot from the gun, take its grip with your right hand and support it by the interlock sleeve with your left hand. Align the hairlines on the safety cap with the marking lines on the building component surface. Then press the gun to the point where the dowel is to be driven, turn the interlock sleeve counter-clockwise well home with your left hand, and abruptly press the grip. In the action, the movable bush of the interlock sleeve moves along the gun axis and actuates the intricate system of the triggering mechanism thereby making a shot.

A new and rather promising mechanism that will supersede within the near future the CMII-3M gun is a III52-1 piston gun intended for fastening with dowels various electrical hardware and supporting structures on concrete, ferroconcrete, brick, and metal bases. Hardware items and structures are secured either by means of a nut turned onto the threaded portion of a dowel screw that has been already driven into the building base or directly by fixing the desired item to a base with a dowel nail driven in by a gun.

The III52-1 single-charge self-triggering piston gun (Fig. 19) depends for its operation on the energy of blast gases and drives in dowels by hitting them with a piston set in motion within the barrel by shooting.

The main parts of the gun are a sleeve and a chamber. The sleeve 5 couples together all the parts, accommodates the front portion of the barrel 9 or 10 (No. 1 or No. 2) and the splitter 8 or 18 (No. 1 or No. 2), and connects the cap 4 or 17 (No. 1 or No. 2). The chamber 11 accommodates a percussive-and-triggering mechanism.

The barrels 9, 10, caps 4, 17, guides 2, 3, 16, splitters 8, 18, and pistons 6, 7, 19 are changeable parts.

The gun fitted with a No. 1 cap and a holder 1 (Fig. 19a) is used to drive dowel screws, up to 70 mm long, directly into a concrete or brick base if the shape of the base surface is smooth enough to fit tightly to the clamp. In driving dowel nails not over 70 mm long into a concrete, brick, or steel base through steel, wood, or any other material or dowel screws up to 70 mm long when the base surface is inconvenient for using a holder, such as shooting in a corner, near a projection, etc., the No. 1 cap is used without a holder.

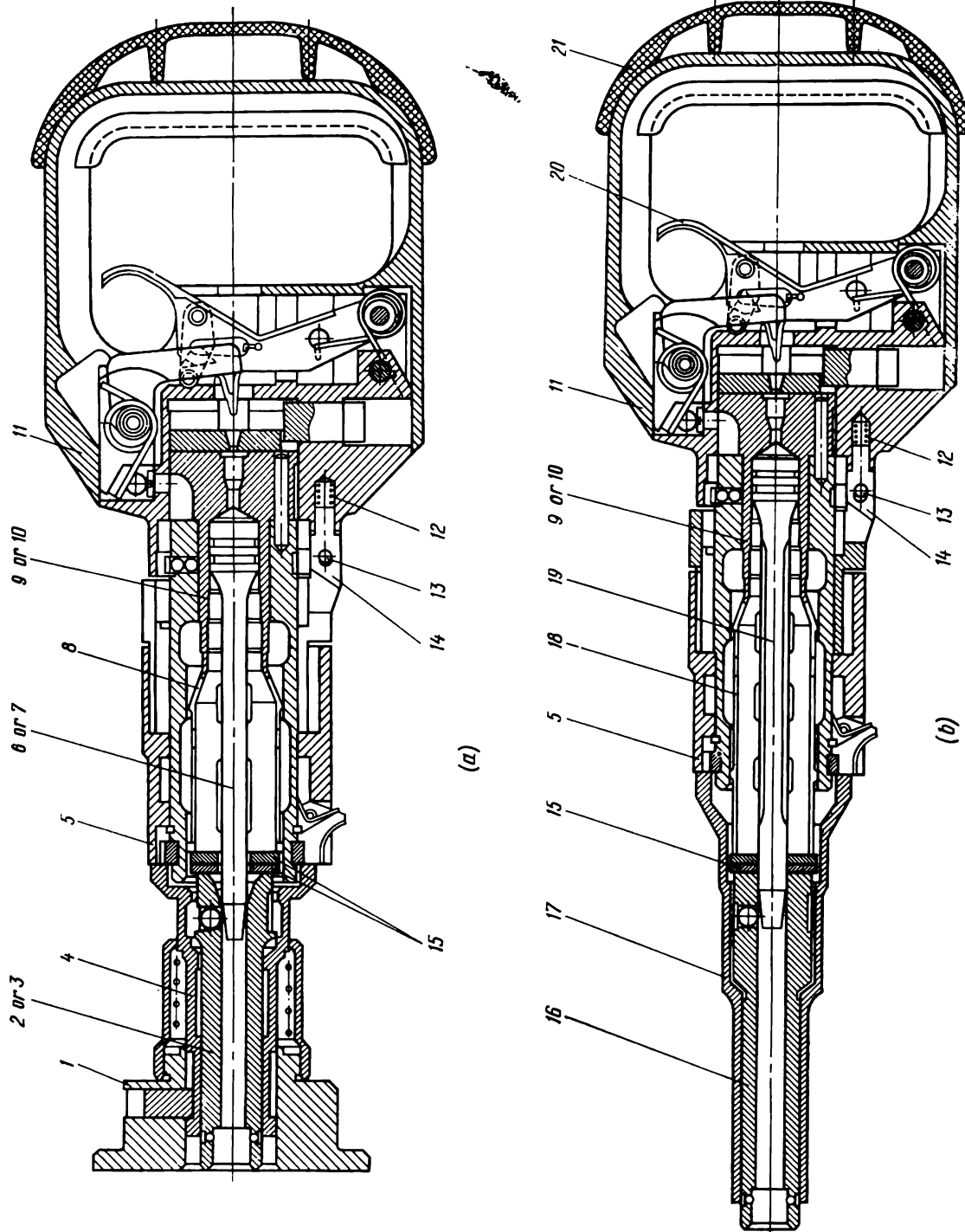


Fig. 19. IIIQ52-1 piston gun

a—with No. 1 cap and holder; *b*—with No. 2 cap; 1—holder; 2—No. 1 guide; 3—No. 2 guide; 4—No. 1 cap; 5—sleeve; 6—No. 1 piston; 7—No. 2 piston; 8—No. 1 splitter; 9—No. 1 barrel; 10—No. 2 barrel; 11—chamber with grip; 12—stop spring; 13—pin; 14—stop; 15—buffer; 16—No. 3 guide; 17—No. 2 cap; 18—No. 2 splitter; 19—No. 3 piston; 20—triggering cock; 21—gun grip

The gun fitted with a No. 2 cap and without a holder (Fig. 19b) is meant for driving dowel nails and dowel screws as long as 70 to 100 mm.

The ПИ52-1 gun uses special no-bullet wadless cartridges, groups Д and К. The group Д cartridges, 22 mm long, are intended for the No. 1 barrel and the group К ones, 15 mm long, for the No. 2 barrel, each furnished with a suitable cartridge chamber.

Each cartridge group used in the ПИ52-1 gun is available in four numbers distinguished by the amount of powder charge and, hence, by the power of explosion. The cartridges of different numbers are identified by the colour of the compressed point of the case, viz., a light charge is identified by a white case, a medium charge by a yellow case, and a heavy charge by a red case.

The ПИ52-1 guns employ heat-treated steel dowel nails ДГП and dowel screws ДВП fitted with washers for their centring within the guide.

As distinct from the existing gun of the СМП-3М type, this one is safe in operation.

The gun is furnished with a special device that prevents making a shot under the following conditions:

- until the cap is held tight against the surface where the dowel is to be driven in;
- with the gun or cartridge chamber incompletely closed;
- with the gun dropped onto a concrete floor from a height of up to 1.5 m.

The dowel driving-in speed is 60 to 80 m/s due to a relatively large mass of the piston. This speed is almost ten times lower than that with the СМП-3М gun, which excludes a rebound of the dowel and its piercing through the building component that may be dangerous for the operator and for personnel working nearby. A low noise of shooting makes it possible to dispense with ear muffs and to shoot as many times a day as desired.

In the case of a building structure having a low strength or when too heavy a cartridge is accidentally used, the piston is stopped by a special buffer 15, thereby preventing the piston from leaving the gun.

To shoot the gun, take it by the sleeve with your left hand and by its grip 21 with your right hand. Press the gun to the surface where a dowel is to be driven in applying a certain force, and without releasing the pressure gradually release the cock 20 with the forefinger of your right hand.

After making the shot, ram the piston to the extreme position and open the gun; in the action, the used case must leave the barrel chamber. If it fails to do so, remove it by the ram. If the dowel is not driven in well home and some of its portion protrudes on the surface, make one more (auxiliary) shot without inserting a new dowel into the gun.

The gun shall be entrusted to skilled workmen having at least rate III qualification in the main trade and trained in the job according to the 20-hour course.

Specifications of the ПИ52-1 gun

Guaranteed number of shots with the use of	
changeable and spare parts	min 25,000
Shots per hour	min 50
Length with No. 1 and No. 2 caps, respectively, mm	385 and 435
Mass, kg	max 4.5

In order to receive a gun and cartridges, the operator must present a certificate and an admission order.

Various pliers (Fig. 20) are used in electrical installation and wiring practice to facilitate some operations in cable routing, splicing, etc.

The *KCH-2M* pliers (Fig. 20a) are designed to skin the wire leads and to cut conducting strands.

The pliers are to be used as follows: insert the insulated wire lead into the slit between the hold-down strip and the insulation cutting knife 1, compress the handles 3 and skin the wire lead. For cutting a conductor make use of cutting knives

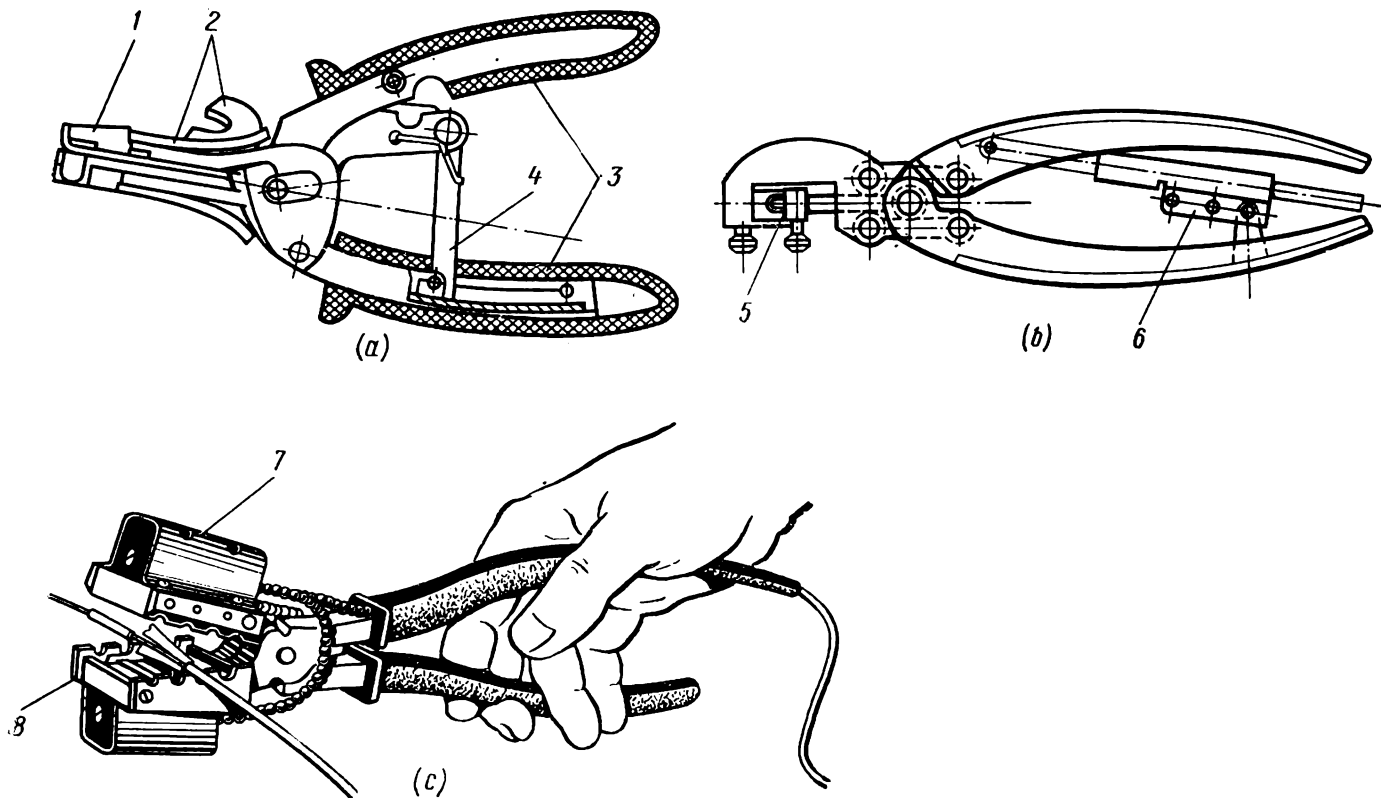


Fig. 20. Electrician's pliers

a—KCH-2M pliers; b—PK-2M pressing pliers; c—TK-1 thermal-operated pliers; 1—insulation cutting knife; 2—wire cutting knives; 3—handles; 4—stop; 5—compressing part; 6—interlocking device; 7—heating element; 8—cutting head

2 provided on the pliers. The knives are changeable parts of the pliers. The motion of the handles is limited by a stop 4.

The *PK-2M* pliers (Fig. 20b) are used to terminate conductors with lugs and also to splice them in troughs by compression. The pliers consist of a compressing part 5, an interlocking device 6, and handles. The compressing part receives appropriate punches and dies for terminating and splicing conductors of various sectional areas. Compression occurs as the handles of the pliers are brought together. In the action, the punch and the die compress the trough or lug inserted inbetween and reliably join these parts with the conductor. The pliers are furnished with an interlocking device which makes it impossible to open them until

compression ceases and to remove the trough or the lug from the compressing part. The handles are reset to the initial position upon the operation of the interlocking device.

The *TK-1 thermal-operated pliers* (Fig. 20c) are used to skin plastic covered conductors having a cross-sectional area of up to 6 mm².

The pliers depend for their operation on a double (mechanical and thermal) action exerted on the insulation being removed. The basic parts of the pliers are

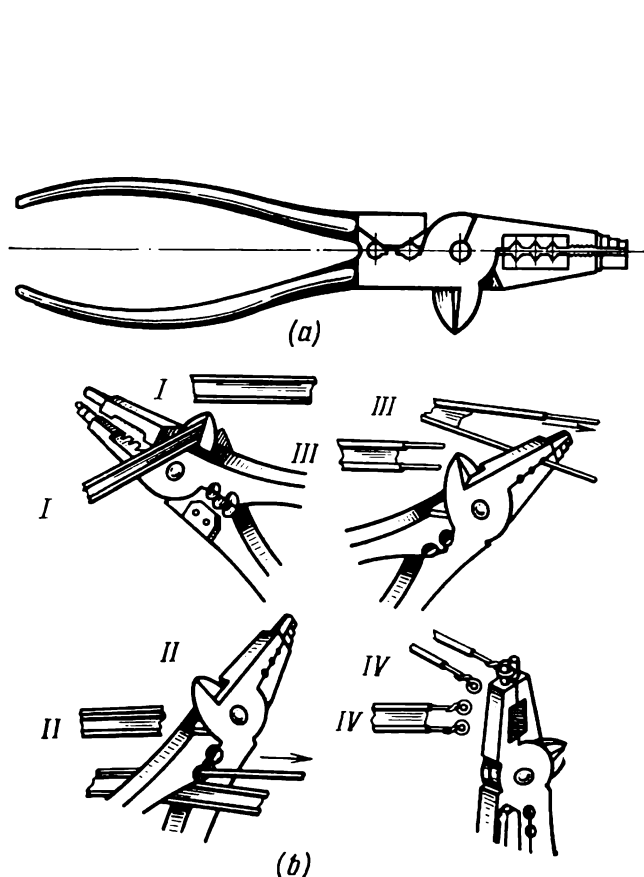


Fig. 21. KY-1 multipurpose pliers
a—general view; b—operations performed by pliers; I—wire cutting; II—removal of separating film; III—insulation stripping; IV—looping the wire end to receive a binding post

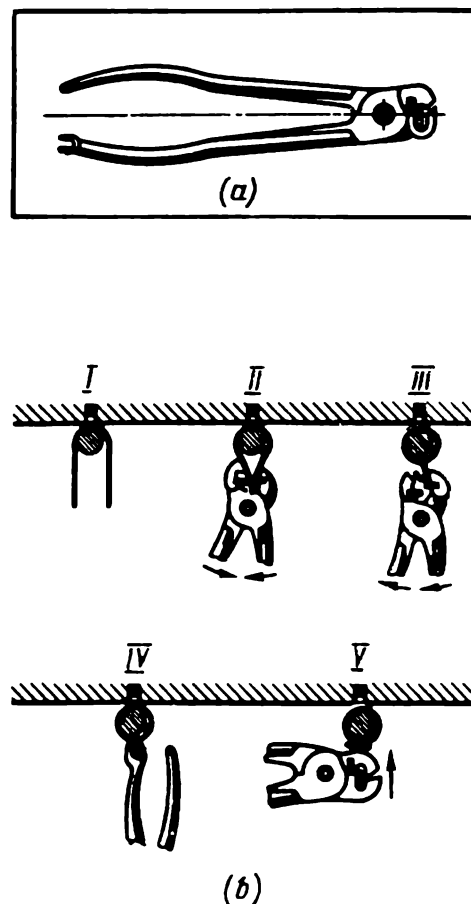


Fig. 22. KH-5 combination pliers
a—general view; b—operations performed by pliers; I—placing cable between fastening strips; II—fitting strips around the cable; III—bending the twin strip through 45 deg; IV—flattening the seam tongue by means of the fork at the end of the handle; V—driving the tongue towards the cable

a cutting head 8 with knives and a heating element 7 that heats the knives to a working temperature of 180 to 200°C.

The pliers facilitate one of the most frequently encountered jobs in the electric wiring practice.

The labour productivity of electricians can be greatly raised by using multipurpose tools, such as multipurpose pliers KY-1 (Fig. 21) and combination pliers KH-5 (Fig. 22).

The *KY-1* pliers (Fig. 21a, b) are designed for wiring assemblies using type ППВ, АППВ, АПН and the like wires, and may function as cutting pliers, flat-nosed pliers, round-nosed pliers, and an electrician's knife.

The *KH-5* pliers (Fig. 22a, b) afford as many as five operations in routing type СРГ (АСРГ), НРГ (АНРГ), БРГ (АБРГ), and the like cables.

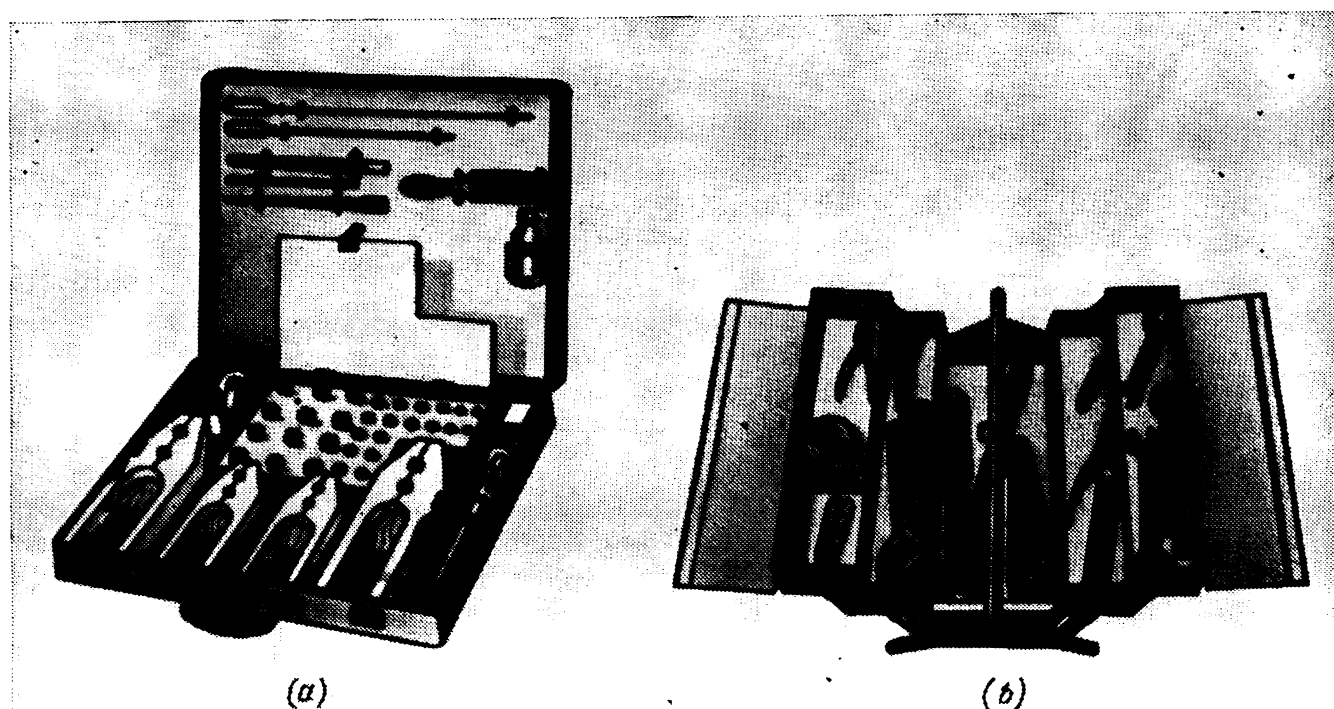


Fig. 23. Tool kits

a—HTC-2 tool kit for thermit welding of aluminium conductors; *b*—HBH-10 tool kit for wiring electrical machines

Individual and crew's tool kits are also available along with multipurpose and combination tools. Such an individual tool kit for thermit welding of aluminium conductors having a cross-sectional area of 16 to 240 mm² is illustrated by Fig. 23a. Fig. 23b shows a crew's tool kit for wiring electrical machines. There are also tool kits accommodated in canvas bags or in special cases for routing cables, wiring the lighting systems, electrical networks, etc.

Review Questions

1. How is electrical work to be organized on site?
2. What is contained in the electrical work execution plan (EWEP)?
3. What is the prefabrication and preassembly division and what functions does it perform?
4. What is industrialized method of electrical work?
5. How important is mechanized equipment for electrical work?
6. Describe the mechanical design and the principle of operation of the TPT-24 pipe bender, the channel-cutting tools, and the ПК-2М pliers.
7. What pyrotechnical facilities do you know and where are they used?

General Information on Buildings and Construction Sites

3.1. Types of Buildings

Modern buildings consist of prefabricated building components. Most large components are foundations, walls, intermediate floors, and roofs.

Buildings are classified according to their purpose as industrial, residential, farm, and special-purpose buildings.

Industrial buildings are those used for accommodating miscellaneous technological pieces of equipment and for carrying out a certain production work, such as assembling machines, rolling metals, testing equipment, etc.

Residential buildings are dwelling houses, hospitals, cinemas, museums, concert halls, schools, theatres, nurseries, etc.

Farm buildings are cattle houses, food and seed stores, farm product processing plants, etc.

Special-purpose buildings are those built to suit special purposes.

Modern industrial, residential, and farm buildings incorporate an intricate set of miscellaneous pieces of electrical equipment and automatic-control facilities; therefore, installation and wiring of such equipment in these buildings is a complicated job requiring a certain knowledge of their building components and methods of construction.

Most pieces of electrical equipment mounted in buildings and constructions are arranged on the surface or inside various building components, such as walls, floors, intermediate floors, etc. Cables and earthing systems are routed on the territory of factories underground. Installation of lighting and power supply wiring systems often involves such operations as drilling through holes, grooves, recesses in various building components with the aid of mechanised tools. Insufficient knowledge of these components may cause damage to them and even destroy them.

With the development of industrialized building methods and the reduction of building terms, the construction work is often combined with the electrical work. That is why electricians must be well acquainted with the organization and technology of building work, and also with the construction of various building components used in state-of-the-art building.

3.2. Building Industry Organization and Technology

A characteristic feature of the modern organization of the building industry is a high degree of prefabrication applied to construction so as to reduce site work to a minimum, and the use of progress charts and critical path schedules.

The building industry is a complex of interrelated processes including main, auxiliary, and handling operations.

Main processes include operations carried out on site and directly connected with the construction of buildings, such as the erection of prefabricated components, erection of wall blocks, brick laying, etc. Main building processes are the leading operations made to create building products.

Auxiliary processes are connected with the construction of facilities required for carrying out main operations such as scaffolds, platforms, etc., and with piling of prefabricated parts and materials, but not with the construction of building components proper.

Handling processes include the delivery of prefabricated constructions and materials to the construction site, and their handling on site. Handling processes, like auxiliary ones, do not yield building components.

A proper and timely execution of building operations primarily depends on the preliminary work done and the technology adopted.

Preliminary work includes:

- (a) demolition, cleaning the site of plants;
- (b) organization of the details of the construction site layout;
- (c) laying communication lines (various pipelines, cables, etc.);
- (d) arrangement of guards, fences, underground roads, and drainage systems;
- (e) delivery and installation of haulage and handling equipment, such as tower cranes, electric hoists, etc.;
- (f) delivery of building equipment and machines;
- (g) construction of storehouses, utility premises, offices, etc.

Preliminary work is the first cycle of construction.

During the second cycle the following jobs are carried out: digging of pits and trenches, installation of foundations and walls of the basement, installation of intermediate floors above the cellar on the datum level. Operations connected with the construction of the underground portions of buildings are referred to as the basement cycle.

The third cycle includes operations connected with the construction of the surface portions of buildings, such as erection of panel walls of the ground and the next floors, installation of intermediate floors, etc.

The fourth cycle concerns finishing jobs carried out before and after fitting out the sanitation, electrical, and other services of the building.

Construction of a building consists of a number of building operations carried out in an appropriate sequence and usually started with earthwork.

3.3. Earthwork

Excavation work is connected with the excavation of topsoil.

The topsoil is the top layer of the earth crust. The topsoils are classified according to their composition (sandy, sandy loam, clay, clay loam), according to moisture content (acidic, wet, water-saturated), according to water permeability (water retentive and draining).

The construction of buildings and building components, just as the routing of various utilities, involves the working of the topsoil by excavation, sometimes by washing out, or by explosion.

In large settlements the topsoil is primarily excavated with the aid of digging machines (excavators), digging and handling machines (scrapers, bulldozers), and drilling machines (automatic drills). The type and capacity of machines are selected depending on the type and size of earth constructions, scope of expected earthwork, relief of the construction sites, and some other considerations.

For washing out the topsoil (by the so-called hydromechanical method) use is made of water-jet monitors.

A water-jet monitor affords a high-power jet of water at a pressure of 8 to 15 kgf/cm² that breaks the topsoil and discharges it over open troughs and pipes to the point where it is to be used.

By explosion the topsoil is crushed, dug out, and heaped around. Explosions are made by means of trinitrotoluene, ammonite, and other explosive materials. The explosive charge is placed in grooves, 5 to 8 mm deep, drilled in the soil, and then fired. Working the topsoil by explosion is carried out according to the plan of explosion operations and only by specially assigned persons.

3.4. Erection of Buildings and Constructions Made of Prefabricated Ferroconcrete Components

Ferroconcrete components arrive at the construction site in a prefabricated state so that the erection of a building is reduced to assembling and installing these pieces by means of mechanized equipment. The operations involved in the procedure are as follows:

- (a) slinging, hoisting, and delivery of building components to the site of erection;
- (b) setting the components in the project-assigned position;
- (c) levelling and temporary fastening of the building components;
- (d) permanent fastening of components erected.

Slinging is the attachment of a load gripping facility (a sling) to a component being erected and to the hook of a hoisting mechanism.

The components being erected must be lifted gradually and lowered to the project-assigned position as exactly as possible. In the process, measures shall be taken to prevent damage to the components already mounted.

The prefabricated building components can be mounted by building-up, building-in, thrusting, turning, and sliding.

The most widely used method of mounting is building-up by lifting one element after another and mounting it on the building components already erected.

For accurate erection and temporary fastening of building components (columns, etc.) use is made of jigs. Wall panels are held in position prior to their permanent fixation by means of screw clamps.

After the elements of a building component are joined together, they must be levelled off in the horizontal and vertical planes.

Their vertical position is checked by a plumb weight or a transit, and their horizontal position by a levelling staff or a levelling gauge. Then the mounted and levelled element is to be permanently fixed in position by the method specified in the project (in most cases, by welding or bolting).

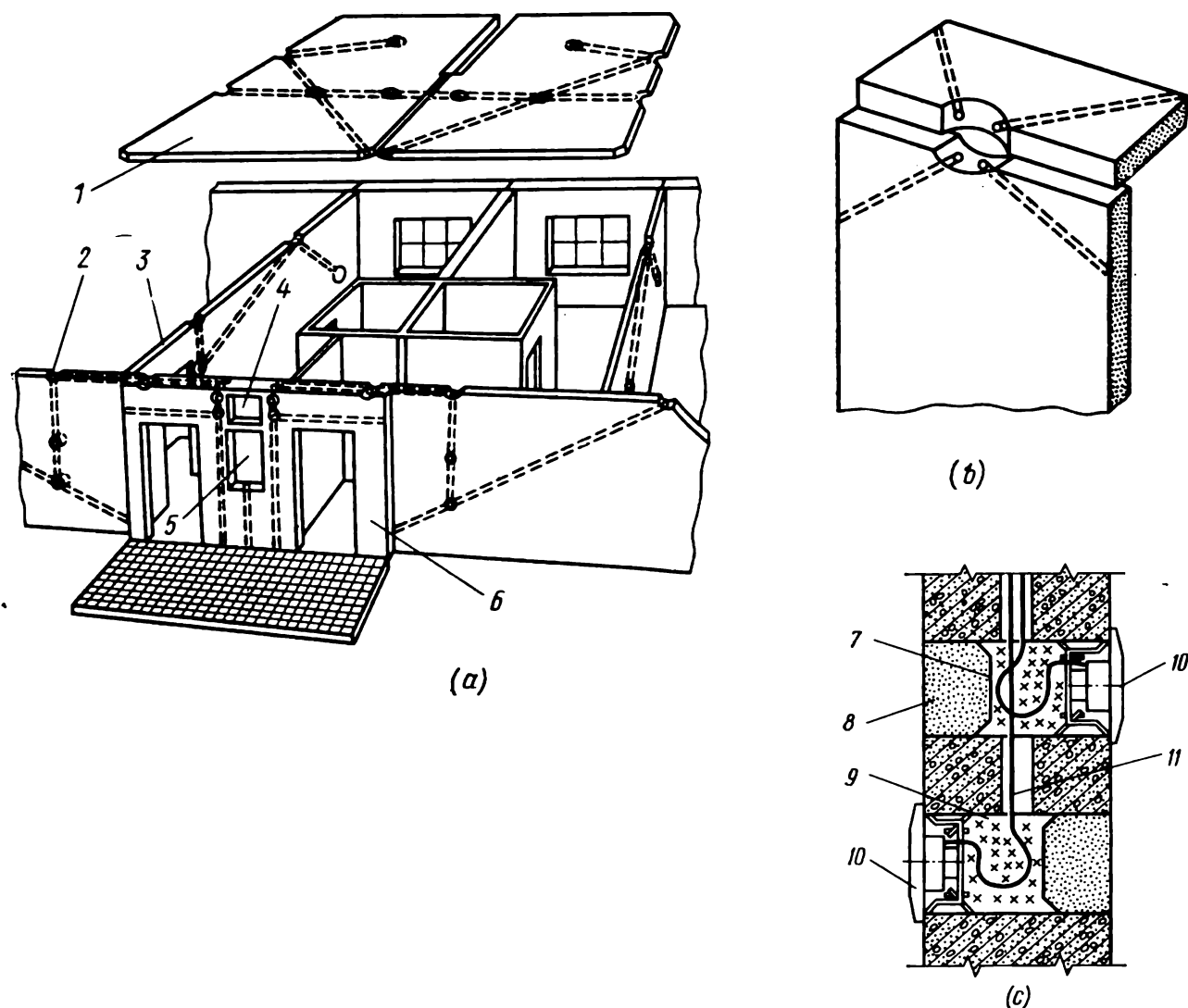


Fig. 24. Construction of a large-panel dwelling house with a raceway wiring system

a—general arrangement of a standard apartment; **b**—ducts joint in wall and intermediate floor panels; **c**—installation of plug sockets on apartment partition; 1—intermediate floor panel; 2—connecting and draw-in recess in wall panel; 3—wall panel; 4—recess for low-current panelboard; 5—recess for apartment wiring distribution board; 6—staircase panel; 7—steel end cap; 8—grouting in cement; 9—noncombustible filler; 10—plug socket; 11—socket connecting wires

The fastening joint must be reliable enough to ensure the desired strength of a building or its component. Some ferroconcrete building components, such as wall panels for multistorey dwelling houses, are manufactured by special factories using a vibration-forming method.

In the course of manufacture of some types of these panels, special grooves, recesses, and raceways are formed with the aid of embedded parts to receive various utilities.

Raceways in which cables or wires travel through the building present a more advanced method as compared with laying them in grooves, slits, or under a plaster, and offer much better technical and economic advantages as they dispense with drilling work, wet plastering and finishing procedures.

Raceways afford a reliable protection against damage to wiring.

Figure 24a, b illustrates raceway wiring systems where wires are routed in the ducts of building elements of a large-panel dwelling house.

The industrialized building method uses prefabricated ferroconcrete building components thereby reducing the amount of finishing jobs and the time of construction.

Standardized building elements have recently found wide application in the building practice. Buildings of various configurations can be constructed out of standard catalogued building elements. Moreover, the number of types of building elements is reduced and more industrialized building is attained.

3.5. Finishing Jobs

Finishing jobs include floor laying, plastering, painting, hanging paper, and glazing.

Floor laying. Floors are laid upon the completion of main building jobs.

A *floor* is a horizontal component of a building arranged at its midspan and functioning to take operating loads. The floor consists of a number of building elements (finish floor, floor lining, hydraulic insulation, thermal insulation, noise insulation, rough floor, and base) that perform different functions.

A *finish floor* is a visible, completed floor surface directly taking operating loads.

A *floor lining* is an intermediate layer between the finish floor and the element laid below.

A *hydraulic insulation* is a floor element that prevents water or any fluid from penetrating through the floor.

A *thermal insulation* is a floor layer that reduces the total heat transfer of the floor.

A *noise insulation* is a floor layer that absorbs noise.

A *rough floor* is a floor element that transmits loads to the base.

A *base* includes intermediate floors that take loads transmitted by other elements of the floor.

Floors can be made of wood, tile, concrete, or plastics depending on the type of the building, purpose of the floor, and construction of the base.

Where the floor is expected to suffer the effect of liquids, as in factory shops for wet production processes, it is inclined at 1 to 5 deg.

The floors must be robust, resistant to light acids, to wear and to mechanical effects.

Plastering. Plastering is a finishing operation consisting in that a substance (portland cement, gypsum, lime putty, etc.) is applied to building structures, such as walls, partitions, ceilings, while it is plastic.

The coat applied is referred to as a scratch coat and after it hardens it is called plaster.

Commercial plaster putties are used where large surfaces are to be plastered. If a building site is located at a great distance from the factory, plaster putties are prepared in mixing machines on site. Compressor and compressorless mixing plants are used for the mechanized preparation and transportation of plaster putties and for applying them to the surfaces being finished.

Plastering of a building component consists in the following.

The surface to be plastered is to be cleaned of dirt and flattened. In order to obtain a good adhesion between the plaster and the surface being finished, the latter is made rough or notched by means of an air-operated tool, a sand-blast apparatus, or any other machine. The surfaces of wooden components are covered with a lathing or flexible reed wicker fixed with lath nails. Metal components to be plastered are coated with oil paint and then covered with wire or with a wire mesh. This done, a spatterdash 10 mm thick is thrown in the form of a wet mortar to provide for the adhesion of the entire scratch coat to the base and its penetration into all the pores and cavities of the surface. The spatterdash is not levelled. The second or floating coat, up to 12 mm thick, is a coarse staff of the desired composition applied over the spatterdash coat while the latter is setting, and levelled. A third finishing or white coat, up to 2 mm thick, may be applied over the floating coat, while it is setting but has not yet hardened, when it is desired to obtain a high-quality plaster. The floating coat is levelled with a hawk (a plasterer's tool in the form of a pinewood square with a handle in the centre). In order to obtain a homogeneous and smooth surface, the floating coat is smoothed by a wooden float; in the action, the surface is wetted with water dripping from a brush.

The stuff composition depends on the material of surfaces to be plastered, operating and environmental conditions. Composite stuff, such as a lime and cement mixture composed of lime, cement, and sand, or a cement stuff mixed with limewash, is used for plastering surfaces expected to resist moisture inside premises.

Apart from standard plasters there are special-purpose plasters that contain special components or in which some components are replaced by different ones. The stuff of thermal insulation plasters, for example, contains asbestos fibre, pumice, or hair instead of sand, and that of noise insulation plasters is composed of cement and a filler of porous crumbles with a grain size of 3 to 5 mm.

Plastering may be made indoors at a temperature over 8°C as measured at a height of 0.5 m above the floor level.

To speed up the drying of plasters, use is made of stationary and mobile flame, electric or gas heaters.

Painting. Painting jobs include operations carried out to finish the indoor and outdoor surfaces by coating them with paints.

According to their purpose, painting jobs are classified as follows:

(a) industrial painting meant to protect building components against corrosion, rotting, inflammation, moisture absorption;

(b) sanitary and hygienic painting intended to keep the premises clean and to maintain proper sanitary conditions in them;

(c) decorative painting made to decorate the building interior or façade.

Painting jobs are finishing operations carried out upon the completion of all the other jobs and may be followed only by finishing clean floors (scraping the parquet, laying the linoleum, etc.) and installing the lighting fixtures.

Painting operations consist of preliminary work, painting, and surface finishing.

Preliminary work includes cleaning, coating with drying oil, priming, filling cracks and cavities with putty, puttying, and wetting the surfaces.

The number and contents of preliminary and painting operations depend on the purpose of painting, material of the surface to be painted, and paint composition (water paint, oil paint, etc.).

The surfaces to be painted are cleaned from dust and dirt with rags or steel spatulas, wet surfaces are dried out, and fat spots are removed with alkali. Rough putty or excess mortar is removed by an electric grinder.

Then the surface is coated with heated drying oil or its emulsion.

Priming paint having an appropriate composition is applied to the surface to be painted to level it and to ensure a uniform absorption of paint.

Priming paints are applied to building components by means of painting sets or guns.

All cavities in the plaster are then filled with putty. Putties consist of a chalk paste and various binders, such as adhesives, oils, emulsions, or varnishes.

In puttying, a uniform coat of putty, 2 or 3 mm thick, is applied to the primed surface. This procedure is followed by levelling the surface and removing the excess putty from the surface.

Polishing involves the surface treatment with special machines, pumice, or emery cloth to eliminate rough areas where the surface was puttied or touched up.

The surfaces to be painted are wetted with water prior to coating them with aqueous lime or cement solutions to ensure a uniform and single-colour paint coat.

The preliminarily treated surfaces are painted by means of painting guns, electric painting guns, air-operated paint sprayers or, for paints of extra high viscosity, by the БКФ-47 machine. Where a small amount of painting work is to be done, paint is applied by power- and hand-operated tools, such as a power-driven roller connected to the painting machine hose, porolon rollers, sprinkling brushes, long-hair brushes, elastic-hair brushes, blunt-pointed brushes, flat brushes, etc.

PVC, polymeric cement, water-dissolved emulsion paints and enamels are used for painting the surfaces of buildings and structures.

When painting is carried out indoors by means of air-operated apparatuses and using fast-drying varnishes and paints containing harmful volatile solvents, the painters must suitably protect themselves with respirator mouth pieces, goggles, special overalls, etc.

3.6. Requirements to Buildings Accepted for Installation and Wiring

Buildings and structures ready for electrical work are to be accepted from building contractors, bearing in mind the following. All dimensions, layout of embedded parts, wiring elements, and raceways or miscellaneous conduits, recesses, etc. made in the course of building to receive wires, cables, and busbars must comply with design data.

Premises accepted for electrical work must ensure:

- (a) normal and safe operation for electricians;
- (b) protection of electrical equipment being installed against precipitation;
- (c) proper operating conditions for hoisting and haulage mechanisms, tools, fixtures, and materials;
- (d) good conditions for wiring systems, electric motors, instruments, and devices after they are installed.

In premises where lighting and power wiring are to be made according to the project, rough floors must be laid, all plastering jobs completed, panels, walls, and ceilings whitewashed and coated with one layer of paint. Finishing jobs are to be carried out by builders upon the completion of electrical work.

Damaged surfaces of building components are to be repaired by builders upon the completion of electrical work.

All the premises where electrical work is to be done must have all the doors hinged, all the windows glazed, and, in cold seasons, heating appliances installed to maintain a temperature of not lower than 10°C.

Most important is the state of building components of electrical premises. Electrical premises may be accepted for electrical work only after they have been whitewashed, asbestos cement pipes at least 100 mm in diameter fitted in the cable entries, and ports are provided in a quantity sufficient for routing all the cables specified by the project.

The layout and depth of asbestos cement pipes must comply with design data; the pipes must be long enough to enter with one end the airway or raceway and with the other end jut beyond the blind area of the building.

The raceways and airways can be used for wiring if they have a normal geometry and are properly floated, and their top edges are covered with angle steel or coated with asphalt varnish to prevent corrosion.

All the supporting structures in electrical premises must be mounted, rigidly fixed, and coated with asphalt varnish.

The raceways and airways must be covered with corrugated steel plates, 5 or 6 mm thick, tightly fitted to them. The plates shall be furnished with flush-mounted handle grips or holes for hooks so as to ensure easy handling in lifting or lowering them during installation and in the course of operation. Reinforced ferroconcrete plates may be employed in some cases.

Doors, locks, ventilation loovers and screens (size 10 × 10 mm mesh) of electrical premises must be accurately fitted and enter the pre-plastered recesses with a certain degree of interference. Their dimensions and geometry must be in full compliance with design data.

The lower edge of the door must be spaced at least 150 or 200 mm from the blind area or from the foundation base projection. When this requirement is met, operating personnel will easily open the electrical premises doors in winter time without cleaning the entrance area from snow and ice.

Water dripping from the roof must be kept away from the electrical premises walls and pilasters to prevent damage to them. To this end, the eaves of the roof must protrude 150 or 200 mm beyond the outer surfaces of the walls.

All the building jobs carried out must comply with the project requirements and standard specifications. All the unfinished operations and all the departures from the requirements of the project and standard specifications must be recorded in the acceptance report by the electrical installation contractors, the date of their elimination must be indicated.

The acceptance report is to be signed by the officials of building and electrical installation contractors.

Review Questions

1. What types of building jobs are considered main?
2. What is the industrialized building method?
3. What are the advantages of raceway wiring?
4. What finishing jobs do you know and how are they carried out?
5. Why is it necessary for electricians to know how building operations are carried out?

Electrical Materials, Accessories, and Fastenings

A great number of electrical materials and parts (cables and wires, insulating materials, hardware, potting compounds and varnishes, solders of various types, etc.) are required for the installation and wiring of electrical equipment.

A proper selection of electrical materials and parts will greatly reduce the cost and raise the operating reliability of electrical equipment installed. That is why the electricians must be well acquainted with the composition or design and purpose of electrical materials and parts most widely used in practice.

4.1. Wires and Cables

Wires and cables are employed to transmit electric power and to interconnect separate components of electrical installations.

4.1.1. Wires

A wire is a single or multiple metal conductor of electric current. A conductor may be built up of one or more strands (a single conductor or a stranded conductor, respectively).

Stranded conductors are more flexible than single conductors.

Conductors used for electric wiring are made of copper or aluminium. Preference is given nowadays to aluminium conductors to save copper whose cost is much higher.

Standard cross-sectional areas of copper conductors are as follows: 0.5, 1, 1.5, 2.5, 4, 6, 10, 16, 25, 35, 50, 70, 95, 120, 150, 185, 240, 300, 400, 500, 800 mm². Aluminium conductors are available of the same standard areas, the minimum one being 2.5 mm².

Copper conductors of up to 10 mm² area and aluminium conductors of up to 25 mm² may be of a single or a stranded type. Those of larger sectional areas are always stranded.

Wires may be bare (without insulation) or insulated.

The conductor of an insulated wire is covered with a rubber, PVC, or vinyl blend material. Some conductors are covered over the insulation with a cotton braid impregnated with a fungicide compound to protect the insulation against mechanical damage and environmental effects. Where the wires are expected to suffer vibra-

tions or mechanical injuries, their insulation is additionally covered with a galvanized steel wire braiding.

Figure 25*a* through *k* illustrates the mechanical design of most widely used bare and insulated wires. Tables 3 and 4 give the wire types, specifications, fields of application, and methods of routing.

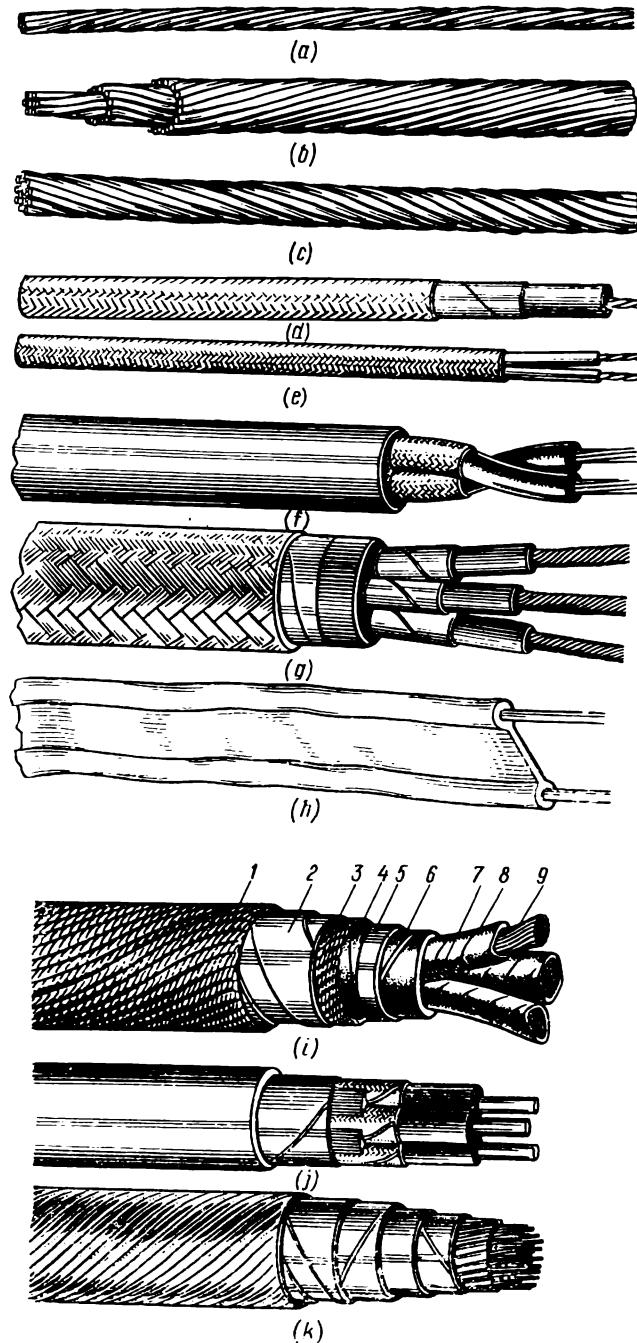


Fig. 25. Electric wires and cables

a—bare aluminium wire A; *b*—bare steel-core aluminium wire AC and ACV; *c*—bare copper wire M; *d*—insulated wire ППГ; *e*—insulated conductors ДППГ; *f*—insulated wire ТППФ; *g*—insulated wire ППШШ; *h*—insulated wire ППБ and АППБ; *i*—paper-covered armoured power cable; *j*—rubber-covered nonarmoured power cable; *k*—control armoured power cable; 1—jute serving; 2—steel band armour; 3—cable jarn; 4—paper layer; 5—aluminium or lead sheath; 6—belt insulation; 7—fillers; 8—conductor insulation; 9—conductor

Table 3

Types and Characteristics of Bare and Insulated Wires

Wire type	Wire description	Conductor sectional area, mm ²
A	Multiconductor aluminium bare wire	16-625
AC	Multiconductor steel-core (zinc-plated steel wire, ultimate strength at least 120 kgf/mm ²) aluminium bare wire	16-400
ACY	Same	120-400
M	Bare copper wire: single conductor of 4, 6, and 10 mm ² area and stranded conductor of 16 mm ² and larger areas	4-400
ПП, ППГ	Wire ПП, rubber-covered copper-conductor with cotton braid impregnated with fungicide compound, for 500 V service Wire ППГ, same as ПП, but flexible	0.75-400
АПП	Rubber-covered aluminium-conductor wire with treated cotton braid, for 3000 V service	2.5-400
ДППГ	Rubber-covered flexible double-conductor wire in common treated cotton braid	0.5-10
ТПРФ	Copper wire with one, two, or three rubber-covered rubber-braided and metal-sheathed conductors	1-4
ПРШП	Rubber-covered rubber-braided copper wire: with one to three conductors with four to ten conductors with five to thirty conductors	1-95 1-10 1-2.5
ПРТО	Rubber-covered, treated cotton braided copper wire	1-120
АПРТО	Same, aluminium	2.5-400
ПВ	Single-conductor PVC covered copper wire	0.75-95
ППВ	Nonflexible flat copper wire composed of two or three parallel insulated conductors separated by vinyl blend	0.75-2.5
ППГВ АППВ АПВ	Same, copper-conductor, flexible Same, aluminium-conductor PVC covered aluminium wire	0.75-2.5 2.5-6 2.5-120

Note. The steel core diameter of the ACY (reinforced) wire is somewhat greater than that of the AC wire.

Table 4

Application and Methods of Routing Bare and Insulated Wires

Wire type	Main application	Routing method
М, А, АС, АСУ	Overhead power transmission lines for up to and higher than 1,000 V service	On insulators mounted on supports or steel towers
ИР-500, АИР-500	Lighting and power networks, indoors and outdoors, in fire-hazard locations, secondary circuits	In insulating pipes, on insulators and cleats, over metal and concrete surfaces with insulating materials placed under wires
ИРГ-500	Connection of electrical machines, devices, and instruments indoors and outdoors, wiring of machine tools	In metal pipes
ИВ, АИВ	Lighting and power networks in premises (dry, humid, extra humid, containing fumes of mineral acids and alkalies) at an ambient temperature not exceeding 40°C; lighting switchboards, starting gear boxes, enclosed cubicles, secondary circuits	In pipes, on insulators and cleats, over metal and concrete surfaces with insulating materials placed under wires
ИГВ	Lighting and power networks, secondary circuits, wiring of machine tools and mechanisms using oils and emulsions	In insulating and metal pipes
ИРТО-500, АИРТО-500	Lighting and power networks in explosion-hazard premises over vibrating surfaces of machines, machine sets, and cranes, or where to open raceways is a problem (for instance, where raceways run under a decorative lining); secondary circuits	In metal pipes and steel conduits
ИРП, ИРПП	Lighting and power networks, secondary circuits, wiring systems of machine tools and mechanisms, under mechanical effects but with oils and emulsions kept away from wiring	Open, with wires held in position by clips
ТПРФ	Lighting and power networks in dry premises with wires liable to suffer light mechanical effects (such as wiring in staircases) and where open wiring must be inconspicuous (in clubs, cinemas, theatres, museums, etc.)	Open, with wires held in position by clips

Table 4 (Continued)

Wire type	Main application	Routing method
AP, APД	Wiring of lighting fixtures in dry premises at a voltage between conductors up to 220 V where wire flexibility is not important	Inside and on the surface of lighting fixtures
ДППГ	Wiring of lighting fixtures outdoors and in humid premises at a voltage of up to 220 V where flexible conductors are needed	Inside lighting fixtures
ПНВ, АППВ, АПН	Lighting wiring systems inside dry and humid premises over walls and ceilings in up to 500-V lines	Open, with wires held in position by nails or clips
АППВС	Wiring in dry and humid premises	Concealed wiring under plaster

4.1.2. Cables

A cable is a single conductor or a multiple insulated conductor designed for the transmission of electric power and covered with a rubber, plastic, aluminium, or lead sheath. A cable covered over the sheath with an armour of steel bands, rectangular or round wire affording protection against mechanical damage is referred to as an armoured cable. A cable whose sheath or armour is not covered with an impregnated jute serving is called a bare cable.

There are power and control cables. Power cables are used to transmit and distribute electric power in lighting and power installations and to interconnect circuit components where it is more reasonable to employ them instead of wires from the viewpoint of economic or technical considerations. Control cables are intended for use in monitoring, signalling, automatic and remote control circuits.

A general-purpose paper-covered cable (Fig. 25i) consists of copper or aluminium conductors 9 of a sector, round or segmental shape, a conductor insulation 8 (oil-rosin treated paper), fillers 7 (bundles of sulphate paper placed inbetween conductors), a belt insulation 6 (oil-rosin treated paper), a lead or aluminium sheath 5, a double-layer bitumenous compound 4 with sulphate paper placed inbetween the layers, a cable yarn 3 impregnated with a fungicide compound, an armour 2 (steel bands, rectangular or round galvanized wire covered with bitumenous composition), a cable serving 1 (jute), and a chalk coat overall.

General-purpose paper covered cables are available of single-, double-, three-, and four-conductor types with a conductor sectional area of 2.5 to 800 mm².

Table 5

Types, Applications, and Routing Conditions of Treated Paper-Covered Power Cables

Cable type	Where routed and environmental conditions	Routing conditions
ACEB, CEB, AEB, AAE	Underground (in trenches) and over walls, outdoors, where mechanical damage may be expected	Cable is not subject to heavy tensile forces
CK, CII	Same	Cable may be subject to heavy tensile forces (due to abrupt slopes, ravines, etc.)
ACBF, CBF, AABF, AEF	In normal atmospheres, indoors, and also in dry and humid ducts and trenches above or below the level of subsoil water, with subsoil water being liable to get inside premises	Cable is not subject to heavy tensile forces nor to mechanical damage
AF, AAF, ABF, AABF	In premises and tunnels with normal atmospheres	Open routing over walls and ceilings as well as over machine tools and mechanisms unless the cable is subject to heavy tensile forces
ACF, CF, CBF, CA	In humid premises, tunnels, in the absence of fumes, gases, and acids detrimental to cable sheath and in the absence of explosion hazard	Open routing over walls, ceilings, building components, etc.
AB, ABF	In premises and tunnels containing chemically active fumes, gases, and acids detrimental to lead sheath	Open routing over walls and ceilings, in ducts, over machine tools and vibrating mechanisms
CFT (CF type may be used if cable section is not over 50 m long)	In prefabricated conduits	Drawn into prefabricated asbestos-cement pipes or into multichannel slabs
ACBB, ACBBF, AOBB, CBB, CBFB, OBB, AAB, ABB, AOB	On vertical sections or abrupt slopes of cable line	At difference in levels up to 50 m with intermediate supports provided for cables
AШB, AАШB	Inside premises, in tunnels, channels, sometimes underground above or below subsoil water	Cable is not subject to tensile forces

The type designations of power cables are to be decoded as follows: the first letter indicates the sheath material (C—lead, A—aluminium, H and HP—fire-resistant rubber, BP—PVC); the second letter stands for the sheathing (A—asphalt-covered, B—armoured with bands; Г—bare, that is, without a serving, K—armoured with round wire, П—armoured with rectangular wire).

The type designation of aluminium-conductor cables begins with letter A and that of cables with lead-sheathed conductors begins with letter O.

The types and fields of application of most widely used paper covered power cables are given in Table 5.

Rubber covered power cables (Fig. 25j) are lead-sheathed, armoured or not armoured, with an overall serving. The conductor cross-sectional area is from 1 to 500 mm². These cables are used for stationary installations rated up to 500 V d.c. and up to 1,000 V a.c., and also for electrical equipment operating on 3 and 6 kV a.c. supply.

Table 6 gives types, fields of application, and environmental conditions of rubber insulated power cables.

Table 6

Types, Applications, and Routing Conditions of Rubber Covered Power Cables

Cable type	Where routed and environmental conditions	Routing conditions
БПГ, БРБГ, НРГ	In enclosed premises with normal atmosphere	Open routing in dry and humid ducts, tunnels, over walls and ceilings, over machine tools and motionless mechanisms
СРБГ, БРБГ, СРД, СРГ, СРПГ, БРГ, БРБГ, НРГ	In humid and extra humid premises	Open routing in external channels, over walls and ceilings, in raceways, indoors
СРА, СРГ, СРБ, СРБГ, БРГ, БРБ, БРБГ, НРГ	In premises with chemically active fumes and gases	Open routing over walls and ceilings, in channels, over machine tools and motionless mechanisms
СРГ, СРБГ, СРПГ, БРГ, БРБГ	In fire hazard locations, in crowded premises (theatres, clubs, cinemas, etc.), in stores of valuables	Same
СРБГ, БРБГ	In explosion hazard premises where electrical equipment may be installed	Same

Control cables (Fig. 25k) may have from 4 to 37 conductors having a cross-sectional area of 0.75 to 10 mm².

These cables are insulated with impregnated cable paper, plastics, or rubber. The cable is covered with a lead, aluminium, or PVC sheath that is protected against mechanical damage with an armour made of steel bands or galvanized wire of round or rectangular section. The steel armour of the type KAE, KCE, KBPE control cables has a jute overall.

Control cables may be laid underground (in trenches), in tunnels, ducts, indoors in various atmospheres, in mines, under water.

4.2. Insulating Materials and Parts

The basic purpose of insulating materials is to insulate current-carrying parts from each other and from earthed elements of an electrical installation. Insulating parts sometimes function to support the current-carrying parts they insulate.

The fields of application of insulating materials in electrical equipment, instruments, and devices depend on their insulating properties, heat resistance, and mechanical strength.

Liquid insulating materials, such as transformer oil, are used to insulate current-carrying parts, to transfer heat from them, and to suppress the arc in circuit-opening devices.

Tables 7 through 12 give brief specifications of insulating materials, varnishes, and adhesives most widely used in electrical work practice.

Table 7

Insulating Pressboard

Pressboard grade	Thickness, mm	Volumetric mass, g/cm ³	Electric strength, kV/mm	Application
ЭВ	0.1-0.6	1.15	10	Liners under conductors routed over metal or ferroconcrete surfaces
ЭВС	0.2-0.4	1.25	11	
ЭВТ	0.1-0.5	1.15	12	
ЭМЦ	0.5-3	0.9	12	Insulation of current-carrying parts of oil-filled devices
ЭМТ	1-3	0.9	11	

Notes. 1. Pressboard of 0.5 mm thickness is available in sheets and rolls and that thicker than 0.5 mm only in rolls.

2. Pressboard sheets measure 900×900, 900×1000, and 1,000×1,000 mm.

Table 8

Paper-Base Laminate Sheets

Type	Thickness, mm	Electric strength, kV/mm, at thickness, mm			Main fields of application
		1	2	3	
I and II	0.2-50	20	16	12	Outdoors under normal climatic conditions (relative humidity of $65\pm 15\%$ at $20\pm 5^\circ\text{C}$ ambient) for up to 1,000 V, 50 Hz service, or in transformer oil
III	5-50	22	18	13	At a relative humidity of up to 95% and $20\pm 5^\circ\text{C}$ ambient for up to 1,000 V, 50 Hz service
IV	2-50	25	20	15	Outdoors in tropics (relative humidity up to 95% at 35°C ambient) for up to 1,000 V, 50 Hz service, or in transformer oil
V-1 and V-2	5-50	28	24	20	In transformer oil for up to 1,000 V, 50 Hz service, or outdoors under normal conditions

Notes. 1. Type I paper-base laminates up to 0.5 mm thick are available in sheets and in rolls and those thicker than 0.5 mm in rolls only.

2. Paper-base laminate sheets measure 650×700 , 650×930 , 700×930 , $930\times 1,030$, $930\times 1,430$ mm.

Table 9

Insulating Tapes

Description or type	Dimensions, mm		Length per reel or roll, mm	Application
	thickness	width		
Rubber-treated tape	0.2, 0.3	10, 15, 20, 25, 50	55-75 — single-sided, 65-85 — double-sided	Insulation of wire and cable connections in wiring lighting and power installations
Resin tape	0.6, 0.8, 1	30, 50, 60, 75	20	Sealing wire and cable entries in stuffing boxes and sleeves. Additional insulation of covered conductors at points of wire keckling
PVC	0.2, 0.3, 0.4, 0.45	15, 20, 30, 50	100-250	Jointing plastic cable sheaths, repair or reinforcement of conductor insulation

Table 10

Basic Specifications of Insulating Compounds

Type of compound	Composition	Approx. percentage of component parts	Temperature, °C				Maximum shrinkage, %	Electric strength, kV/mm	Application
			heating	flash	cracking	drop			
МП-1	Rosin Motor oil	30 70	110-120	160	-20	Not specified	—	35 kV for 1 min	Scalding sleeves and cables in wiring
МК-45	Rosin Transformer oil	70-75 30-25	130-140	185	-8	45	7	35 kV for 1 min	Filling sleeves and locking unions for up to 35 kV service
МБ-70	Bitumen БН-III	50	160-185	230	-12	70	9	35	Filling cable sleeves and terminations for up to 10 kV service, routed underground or in nonheated premises at a temperature not lower than minus 10°C
	Bitumen БН-V	50							
МБ-90	Bitumen БН-III	20	185-195	230	-10	90	9	35	For the same cable sleeves and terminations on the surface or in heated premises
	Bitumen БН-V	80							
МБМ-1 (Э-3)	Compound БМ-70	85	140-150	170	-45	50-60	8	35	For filling cable sleeves and terminations for up to 10 kV service, laid outdoors and in nonheated premises at an ambient temperature down to -35°C
	Transformer oil or compound	15							
	МБ-90	15							
МБМ-2	Compound МБ-90	80	140-150	170	-35	55-60	8	35	For the same cable sleeves and terminations, but at ambient temperatures down to -45°C
	Transformer oil	20							

Table 10 (Continued)

Type of compound	Composition	Approx. percentage of component parts	Temperature, °C				Maximum shrinkage, %	Electric strength, kV/mm	Application
			heating	flash	cracking	drop			
M1B	Polyisobutylene	28	150-161	—	—45	—	7	35 kV for 1 min	Filling outdoor HV bushings and cable sleeves
	Transformer oil	42						and further raised to 40 kV	
	Capacitor vaseline	30							
M3П (rubber softener)	Wax	—	90	—	—	—	—	—	Filling protective casings of cable jointing sleeves and locking unions for 6 to 35 kV service, routed underground and under water

Note. Insulating compounds are used for filling cable sleeves, mast boxes, end bells. They must conform to specified frost resistance (as low as minus 45°C), moisture resistance, electric strength, ambient temperature range (+60 to -45°C), and shrinkage (at temperatures ranging between -45 and +100°C).

Insulating Varnishes and Enamels Used in Installation and Wiring

Table 11

Varnishes and enamels	Solvent	Colour	Number of layers	Consumed material, g/cm ² , if applied by		Drying time of one layer, h	Application	Approx. service life of coat, years
				brush	sprayer			
Bituminous varnish	Paint thinner or xylene	Black	1	100	125	24	Protection of metal supporting structures in moderate climates	5
Same with 10 or 15% of aluminium powder added	Same	Silver-aluminium	1	90	120	24	Same	4-5
No. 177 bituminous varnish	White alcohol	Black	1	100	125	24	Same	2-3

Table 11 (Continued)

Varnishes and enamels	Solvent	Colour	Number of layers	Consumed material, g/cm ² , if applied by		Drying time of one layer, h	Application	Approx. service life of coat, years
				brush	sprayer			
Same with aluminium powder or AJI-177 dye added	White alcohol, petrol, turpentine	Silver-aluminium	2	90	120	16	Same	—
Coal varnish (Kuzbass varnish)	Toluene, paint thinner	Black	2	100	125	6	Protection of steel structures and pipes laid in soil	4-5
Primer ГФ-032 (old No. 138) or BXГМ	Paint thinner or P-4	Red, brown	1	180	200	24	Protection of metal structures of lines or substations operating in industrial or humid atmospheres	—
Perchlorvinyl enamel ПХВ-26 or ПХВ-24	P-4	Same	2	250	300	1		4-5
Primer B-329, Д-329, E-329	P-5	Same	2	180	120	24	Protection of oil-filled devices and metal structures operating in subtropics	5-6
Perchlorvinyl enamel ПХВ-714 or ПХВ-715	P-5	Silver-aluminium, gray	3	250	200	2	Same	—
Primer XC-010 or BXГМ	P-4	Red, brown	2	180	120	24	Protection of metal structures in atmospheres containing chemically active gases, acids, and alkalies	4-5
Chemically resistant perchlorvinyl enamel XCЭ-26	P-4	Same	6	250	200	1		—

- Notes. 1. Enamels and varnishes are used to make protective coatings raising the electric strength of parts or protecting them against corrosion and moisture. According to their purpose, insulating varnishes are classified as impregnating, coating, and adhesive. According to drying conditions, varnishes are classified as air-drying (drying at a temperature of 20 to 25°C) and baking varnishes that dry at a temperature as high as 100°C.
2. Varnish coats are to be applied to degreased and thoroughly cleaned surfaces (cleaned with a sand blaster or a metal brush). If a piece of equipment being varnished is expected to operate in atmospheres saturated with industrial chemically active impurities, it will be good practice to apply additional coats of varnish on its surface and to put petrolatum above the last layer.
3. Aluminium powder ПР-3 or ПАР-4 is to be added directly before use in the amount of 10 to 15 mass parts per 100 parts of varnish.

Table 12

Adhesives

Type	Effective period, min	Application	Methods of application
БФ-2 БФ-4	30-40	Bonding metals, porcelain, glass, wood, plastic materials, etc. Filling cracks in porcelain and sealing joints in tanks of electrical equipment (power transformers, oil circuit breakers, etc.)	Clean surfaces of parts to be joined and wipe them with acetone, apply two layers of adhesive on each surface, allowing each layer to dry out for 1 h at 20°C or for 15 min at 60°C, compress the two parts to each other applying a force of 10-15 kgf/cm ² and expose to a temperature of 150 to 160°C for 40 or 50 min in a drying cabinet
88-H	30-45	Bonding rubber to rubber and rubber to metal, porcelain, glass, wood, and to miscellaneous plastics	Clean the rubber surface with a cord brush or a file, wipe it with petrol, dry out, apply a layer of adhesive and allow it to dry for 3-5 min. Apply two layers of adhesive to porcelain or any other surface to be stuck to rubber, dry them out for 8 to 10 min, press the parts to be joined to each other and expose them to a temperature of 20 to 40°C for 24 hours
БМК-5 БМК-5М	30-50	Bonding electrical hardware to surfaces of building components for open wiring	Apply a layer of adhesive, 0.3 to 0.5 mm thick, to the clean surface of the building component and to the surface of the part to be attached to the former, fit the part in position and tightly press it for 10 to 12 s

4.3. Accessories and Fastenings

Accessories are miscellaneous bushings, end bells, cleats, clamps, draw-in boxes, jointing and splice sleeves, and fittings employed in wiring. Fastenings are used to secure miscellaneous parts, wires and supporting structures to building elements.

Cylindrical cast-iron draw-in boxes are mounted to draw conductors into steel conduits routed over the surfaces of building components indoors in normal atmospheres.

The box (Fig. 26a) is closed with a stamped steel cover secured thereon with two screws. The cover is set on a rubber or pressboard gasket. The box pipe unions are

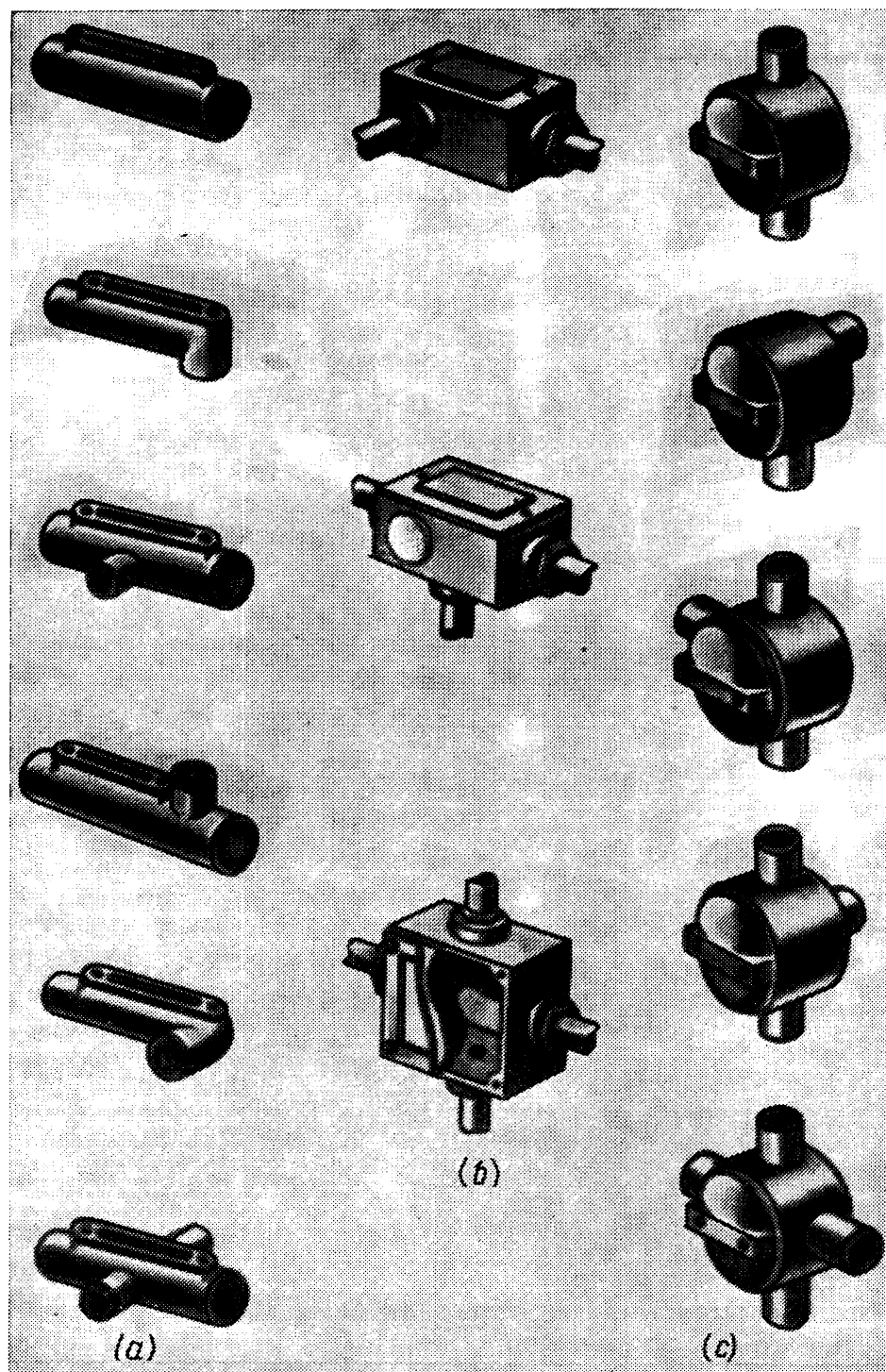


Fig. 26. Boxes and fittings (draw-in, angle, tee, and cross-connecting) for drawing-in, connecting, and splicing the wires laid in steel pipes

a—cast-iron boxes; *b*—steel boxes; *c*—fittings

fitted with thread to receive steel pipes. The diameter of the pipe unions is from $\frac{3}{4}$ to $1\frac{1}{2}$ in.

Rectangular steel boxes (Fig. 26b) are used for splicing conductors laid in open steel pipes in premises with normal and humid atmospheres.

In extremely humid and explosive atmospheres conductors are joined and spliced in fittings (Fig. 26c).

Electric wiring elements are fastened by means of clamps, steel strips with fasteners, tapes with snap fasteners, and perforated tapes (Fig. 27a through i).

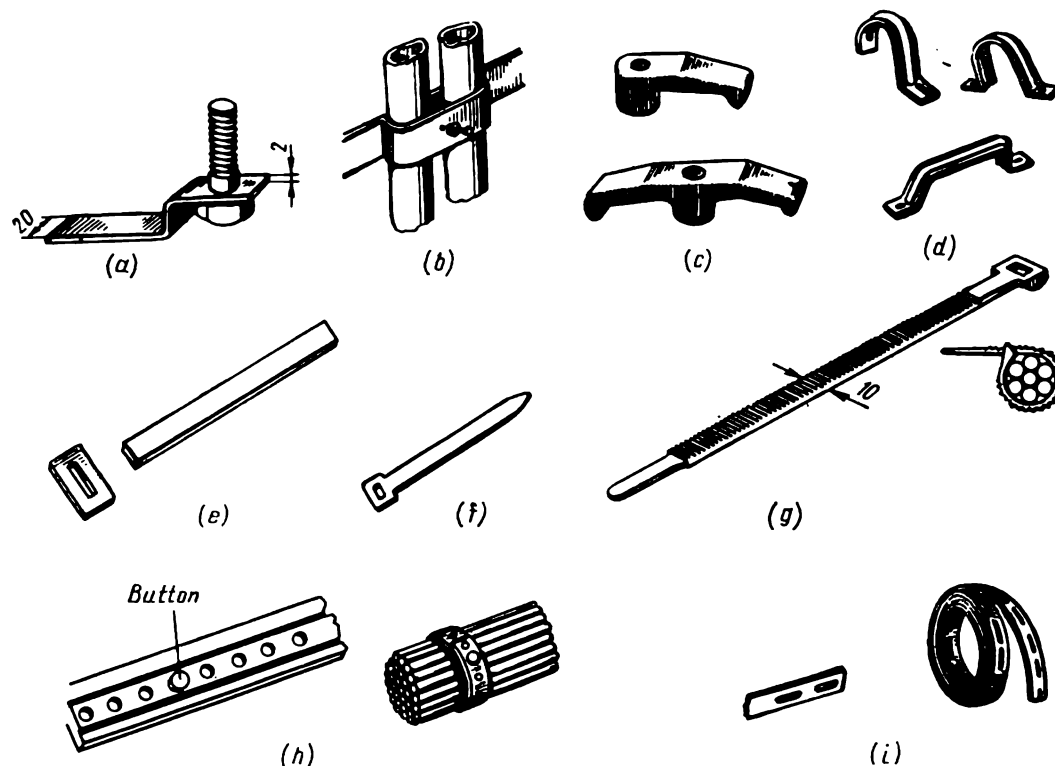


Fig. 27. Fastenings for wiring systems

a—fastening lug with a bolt; *b*—strap; *c*—single- and double-ended plastic clamps; *d*—clips with one and two fastening lugs; *e*—steel strip complete with clasp; *f*—clasp-terminated strip for banding the wires; *g*—clasp-terminated toothed plastic strip; *h*—PVC band with snap fastener; *i*—perforated wiring tape

Electrical pieces of equipment, supporting structures, and fastenings are fixed to building elements by means of dowels (Fig. 28). Dowels having an outer thread of M6, M8, and M10 (Fig. 28a) are used for detachable fastening while dowel nails (Fig. 28b, c) are intended for dead fixation of electric wiring systems and parts to brick, concrete, ferroconcrete, and steel surfaces of building components. The dowels (Fig. 28a, b, c) are available of lengths from 25 to 80 mm. The dowels are driven into building components by means of CMII or III guns.

The dowel illustrated by Fig. 28d has a split nut and serves for a detachable fastening. Its screws have an outer thread of M4 to M16. The breaking force is 200 to 900 kgf.

Fibre-filled metal dowels (Fig. 28e) are used for a detachable fastening of parts with a breaking force of 50 to 80 kgf. These dowels are available of a length from 25 to 70 mm and a diameter of 5 to 8 mm.

Plastic dowels (capron, polythene, Fig. 28f, g) taking forces from 100 to 600 kgf have found wide application. They are available of an outer diameter of 7 to 20 mm

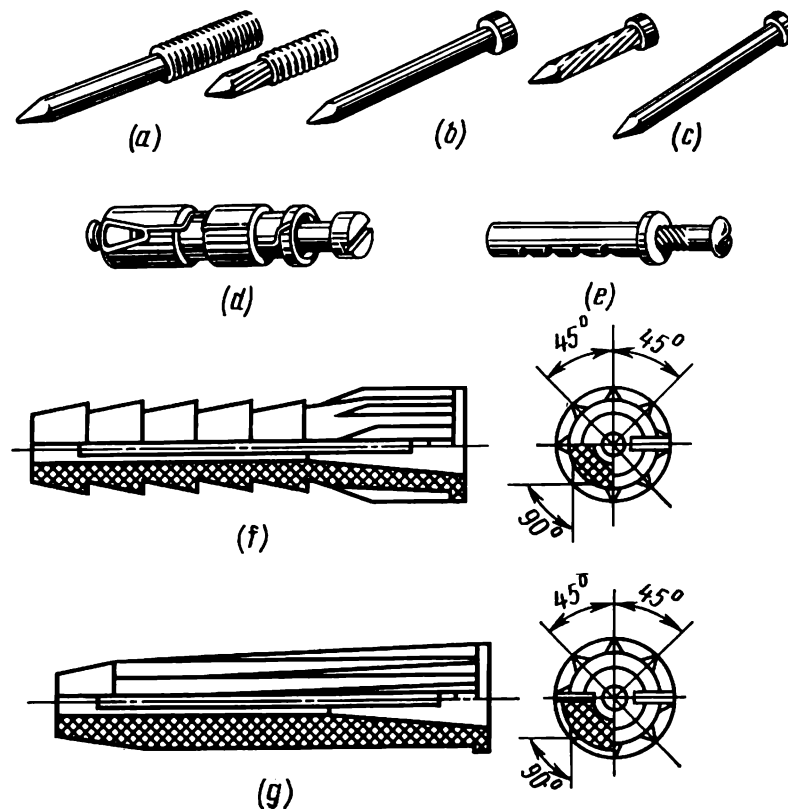


Fig. 28. Dowels

a—ДВ dowel screws; *b*, *c*—ДГ and ДГР dowel nails; *d*—expansion-nut dowels; *e*—crimped-filler dowel; *f*—dowel with circular plastic ribs; *g*—bright tapered plastic dowel

and a length of 25 to 100 mm and are suitable to drive in screws and bolts, 3.5 to 14 mm in diameter.

Stay dowels (Fig. 28d, e, f, g) are driven into seats of the corresponding length and diameter pre-drilled in the building components.

The dowel is held tight within the seat due to the expansion of the sleeve as a bolt or a screw is driven in.

4.4. Solders, Soldering Pastes, and Fluxes

In wiring and routing cable lines use is made of various solders (Table 13), soldering pastes (Table 14), and fluxes (Table 15) for connecting and splicing wires and cable conductors and for connecting earth conductors to lead and aluminium sheaths of cables.

Table 13

Composition of Most Widely Used Soldering Pastes

Composition No.	Percentage							
	animal fat or stearine	rosin	ammonium chloride	zinc chloride	water	petroleum jelly	petrolatum	hydrochloric acid (etched)
1 (Mosenergo)	30	50	10	5	5	—	—	—
2	30	30	5	25	10	—	—	—
3	5	2.5	2	20	5.5	—	65	—
4 (Mosenergo central HV laboratory)	5	2.5	2	20	5.5	65	—	—
5 (Lenenergo)	—	11	—	—	—	64	—	25

Table 14

Composition of Most Widely Used Solders

Solder type	Percentage								Mass, g/cm ³	Melting point, °C	
	tin	lead	antimony	copper	silver	zinc	cadmium	aluminium		start	finish

Lead-tin solders

ПОС-90	89-90	Remaining quantity	max 0.15	0.8	—	—	—	—	7.6	183	222
ПОС-61	59-61	Same	max 0.8	0.1	—	—	—	—	8.6	183	225
ПОС-50	49-50	Same	max 0.8	0.1	—	—	—	—	8.9	183	230
ПОС-40	39-40	Same	1.5-2	0.1	—	—	—	—	9.3	183	235
ПОС-30	29-30	Same	1.5-2	0.15	—	—	—	—	9.8	183	245
ПОС-18	17-18	Same	2-2.5	0.15	—	—	—	—	10.2	185	277
ПОС-4	3-4	Same	5-6	0.15	—	—	—	—	10.7	245	265

Solders for connecting aluminium conductors

ПА-15	—	—	—	—	—	85	—	15	—	450	500
ЦКО	36	—	—	—	40	24	—	—	—	250	300
ЦМО	40	—	—	1.5	—	58.5	—	—	—	400	425
П150А	38.7	—	—	—	—	3.8	57.5	—	—	150	—
П170А	79	—	—	20	—	—	1	—	—	170	—
П200А	90	—	—	—	—	10	—	—	—	200	—
П250А	80	—	—	—	—	20	—	—	—	250	—
П300А	—	—	—	—	—	60	40	—	—	300	—

Table 15

Composition of Fluxes Most Widely Used for Soldering and Welding Aluminium

Flux type	Composition, %					
	potassium chloride	sodium chloride	boron chloride	lithium chloride	sodium fluoride	cryolite, type K-1
KM-1	45	20	20	—	15	—
AΦ-4A	50	28	—	14	8	—
BAMH	50	30	—	—	—	20

Note. Fluxes are prepared in the form of a consistent and thick compound; to this end 100 g of powdered flux shall be mixed with approximately 35 g of water.

Review Questions

1. What are protective and insulating elements of a power cable?
2. Where are control cables used?
3. What is the purpose of insulating materials?
4. What is the purpose of dowels and how are they used?
5. What is the composition of the ИОС-40 lead-tin solder?
6. What solders are used for soldering aluminium conductors and cable sheaths?
7. What is the composition of a flux (any one at your choice) used for welding and soldering aluminium conductors and cable sheaths?

Installation and Wiring of Lighting Systems

5.1. Lighting Systems, Illumination, Photometric Quantities

5.1.1. Lighting Systems

A lighting system is a special electrical installation designed to illuminate territories, buildings, premises, and structures.

A lighting system of a large dwelling house or an industrial building is a sophisticated complex incorporating switchgear, main and branch-circuit lines, various measuring instruments, lighting fixtures (lights) and sources, supporting structures, and fastenings. A characteristic feature of any lighting system is a great variety of schematic and wiring circuit arrangements used, constructions of lighting fixtures and sources. High-power lighting systems are furnished nowadays with automatic and remote control facilities.

Lighting may be general, spot, combination, operating, and emergency depending on the purpose of lights of a lighting system.

General lighting serves for illuminating a whole building or a part of it. Spot lighting is meant to illuminate working places, pieces or surfaces, such as illumination of a part being treated or a tool of a lathe.

Combination lighting is a combination of general and spot lighting.

Operating lighting functions to afford normal operation of production and auxiliary sections of an industrial plant.

Emergency lighting is used in the event of a failure of operating lighting to ensure normal operating conditions or to evacuate personnel. Emergency lighting is provided in industrial premises, passageways, staircases, aisles, and thoroughfares. The emergency lighting fixtures must be distinguished from the other ones by their colour and construction. They are to be connected to an electrical network isolated from the operating lighting system.

General, local, operating, and emergency lighting fixtures installed in premises with a normal atmosphere are meant for 127 or 220 V power supply and those mounted in dangerous or extra dangerous locations are to operate on 12, 24, or 36 V supply.

There are also portable lights, guard lights, and overall lights.

Portable (repair) lights are essentially portable lamps connected to 127 or 220 V supply under normal conditions or to 12 V supply under abnormal conditions and outdoors.

Guard lights are mounted over the wall of a guarded area so that the latter and the territory adjacent to the wall are illuminated.

Overall lights are installed on high buildings, smoke-stacks, and the like constructions to ensure safety for aircraft flying in the dark.

The main requirement to a lighting system is to afford illumination specified by the standard.

The illumination level is specified with due account of visual perception, such as size of objects of vision, their contrast in respect to the background and the background radiant energy, presence of exposed bodies dangerous when in contact (open current-carrying parts, nonguarded rotating parts, etc.), presence of extremely bright surfaces within the field of vision (electric or gas welding, metal melt, radiating light, red-hot parts being machined, industrial lights, etc.).

The level of illumination at certain sections of a room or of working places is raised by arranging general lights at particular spots, by using spot lighting, or more adequate lighting fixtures, or bulbs of higher power.

In mounting electric lighting systems specified illumination must be ensured so as to improve working conditions, to raise the productivity of labour, to provide for the visual comfort of the workmen to raise the quality of products manufactured, and, at the same time, to save electric power consumed for illumination.

Electrical lighting systems are mounted in accordance with a project containing illumination art calculations and lighting system calculations. Due considerations are given to the characteristics of technological processes, operating conditions, and environmental conditions. Voltage drop calculations are based on the minimum consumption of conducting materials (wires, cables, bus-bars, etc.). The voltage across most distant lamps must be at least 95 per cent of the rated value for emergency and outdoor lighting systems using lighting fixtures, 97.5 per cent for operating lighting systems within industrial plants and for flood lights mounted outdoors.

Under normal conditions the voltage across the lamps shall be maximum 102.5 per cent of the rated value.

The rated load of a lighting supply circuit is determined by multiplying the installed power of the lamps found from lighting art calculations by the demand factor that equals 0.6 for switchgear installations, substations, stores and auxiliary premises of plants; 0.8 for laboratories and medical institutions; and 1.0 for industrial premises.

Lighting systems are supplied with power from separate lighting transformers or from transformers that feed at the same time industrial power consumers (electric motors, welding sets, etc.).

5.1.2. Photometric Quantities

The main photometric quantities are the luminous flux, the illuminance, and the luminous intensity.

Surrounding objects emit radiant energy that produces visual sensation. This is essentially the energy of electromagnetic waves propagating in space. One of the basic characteristics of electromagnetic waves is the wavelength that varies between fractions of a millimetre and hundreds or thousands of metres.

The human eye responds to a rather narrow wave range of 380 to 760 nm*.

* nm is the unit of measurement of length equal to 10^{-9} m.

Radiations within the above-mentioned wave range producing visual sensation in the form of coloured light spots are referred to as the visible region of the spectrum of electromagnetic waves. The human eye cannot respond to wavelengths beyond the visible region of the spectrum.

Wavelengths within the visible spectrum are distinguished one from another by their ability to excite in the human eye various colour sensations.

The radiant energy evaluated by its capacity to produce visual sensation is called the *luminous flux*.

The unit of measurement of luminous flux F is lumen (lm).

Illuminance is the quantity of a luminous flux per unit area. The intensity of surface illumination is evaluated by the density at which the luminous flux is distributed over the illuminated surface. The unit of measurement of illuminance is the lux (lx).

Illuminance E is known as the ratio of luminous flux F incident on a surface to its area S , that is,

$$E = \frac{F}{S}$$

The lux is the illumination on a surface of 1 m² on which a flux of 1 lm is uniformly distributed, that is

$$1 \text{ lx} = \frac{1 \text{ lm}}{1 \text{ m}^2}$$

Luminous intensity characterizes luminous flux distribution of a light source and the luminous flux density in a given direction. This quantity is essential because there are light sources that radiate light at a different intensity in different directions.

The unit of luminous intensity in the SI system of units is the candela (cd) which is the main internationally adopted photometric unit.

Surrounding objects are capable of reflecting, absorbing, and transmitting a luminous flux. These abilities are known as *luminous properties of bodies*.

A luminous flux F that falls on a body is generally divided into the following three components:

- luminous flux reflected by the body (F_r),
- luminous flux absorbed by the body (F_{ab}),
- luminous flux transmitted through the body (F_{tr}).

The F_r/F ratio defining the portion of luminous flux reflected from the body is known as *reflection factor*. The F_{ab}/F ratio showing the portion of a luminous flux absorbed by the body is known as *absorption factor*. The F_{tr}/F ratio defining the portion of a luminous flux transmitted through the body is known as *transmission factor*.

Luminous properties of bodies are also characterized by how they reflect and transmit light. Reflection and transmission of light are distinguished as diffuse, specular, and specular-diffuse.

5.2. Electric Light Sources, Devices, and Lighting Fixtures of Lighting Systems

5.2.1. Electric Light Sources

Electric light sources are incandescent lamps, low-pressure fluorescent lamps, and high-pressure mercury vapour lamps.

Most popular of them are *incandescent* lamps (Fig. 29a).

Incandescent lamps depend for their operation on the conversion of electric power supplied to their filaments into the energy of visible radiations exciting in the human eye a visual sensation of an almost white colour. This conversion takes place within the lamp as its tungsten filament heats to a temperature of 2,600 to 2,700°C. The filament does not burn out because the melting point of tungsten is as high as 3,200 to 3,400°C, which is much higher than the filament heating temperature. Besides, the filament is placed in a bulb from which all air is evacuated or which is filled with inert gases (a mixture of nitrogen, argon, and xenon), so that oxidation of metal does not occur.

The service life of incandescent lamps varies within a wide range and depends on operating conditions, such as stability of supply voltage, mechanical effects (jolts, shocks, vibrations), ambient temperature, etc. The average service life of commercial incandescent lamps is 1,000 to 1,200 h.

With time the filament gradually evaporates under the effect of high temperature, grows smaller in diameter and then burns out. The higher the filament temperature, the greater is the luminous efficiency of the lamp, but also the more intensive is evaporation of the filament and, hence, the shorter is its service life. Therefore, a reasonable filament temperature is specified for incandescent lamps to afford a sufficient luminous efficiency and an adequate service life.

Incandescent lamps with bulbs from which all air is evacuated are known as *vacuum* lamps and those with bulbs filled with inert gases are called *gas-filled* lamps.

Other conditions being equal, the gas-filled lamps are characterized by a higher luminous efficiency as compared with the vacuum lamps as the gas held within the bulb under a pressure prevents evaporation of the filament, with the result that a higher filament temperature can be used. A drawback of gas-filled lamps is that a certain heat loss of the filament takes place due to the convection of the gas contained within the bulb.

A certain reduction in the heat loss is attained through the use of gases having a low heat transfer. One more method of reducing heat loss is reducing the size and selecting an appropriate design of the filament. Filaments are made in the form of a solid coil or a coiled coil.

One of the basic characteristics of any incandescent lamp is the luminous efficiency. *Luminous efficiency* C of a lamp is the ratio of luminous flux F to its power P , that is,

$$C = \frac{F}{P}$$

The luminous efficiency of incandescent lamps rises with power.

The power of commercial incandescent lamps rated at 127 and 220 V supply ranges from 15 to 1,500 W.

The main disadvantage of incandescent lamps is their low luminous efficiency. Only 2 to 4 per cent of input power is converted into the energy of visible radiations exciting in the human eye a visual sensation, the bulk of remaining power being transformed into heat energy.

Fluorescent lamps are more advanced light sources. They have found wide application in the illumination of industrial plants, offices, educational and medical institutions.

A fluorescent lamp (Fig. 29b) is a hermetically sealed glass tube 7 whose interior surface is covered with a thin layer of phosphor. All air is evacuated from the tube; a small amount of inert gas (argon) and a metered drop of mercury are introduced therein. Coiled-coil tungsten electrodes 3 are secured at the ends of the tube interior in glass pins 2 and are connected with two-pin bases 1 that function to connect the lamp to supply mains through special lamp holders.

Applying voltage to the lamp causes an electrical discharge in mercury vapours between its electrodes, with the result that the lamp starts emitting light. The electrodes of fluorescent lamps are coated with electron-emitting materials, such as oxides of strontium, barium, or calcium to afford a more intensive emission of electrons.

The lamps are distinguished by the colour of light they emit, viz., daylight lamps (ЛД), white lamps (ЛБ), cold-white lamps (ЛХБ), warm-white lamps (ЛТБ), etc. Where accurate equivalence of daylight is desired, for example, in coloured reproduction printing rooms, in artists' studios, in textile factories, etc. use is made of the ЛД lamps affording a daylight-quality illumination.

Low-pressure fluorescent lamps are gas-discharge light sources.

Low-pressure fluorescent lamps are available of 15 and 20 W power for 127 V supply and 30, 40, 80, 125 W power for 220 V supply. The service life period within which fluorescent lamps operate normally is about 5,000 h on condition that they are started infrequently, operate on a steady supply voltage and at a normal ambient temperature (not exceeding 15-25°C).

Modern lighting systems of industrial plants widely use high-pressure mercury-

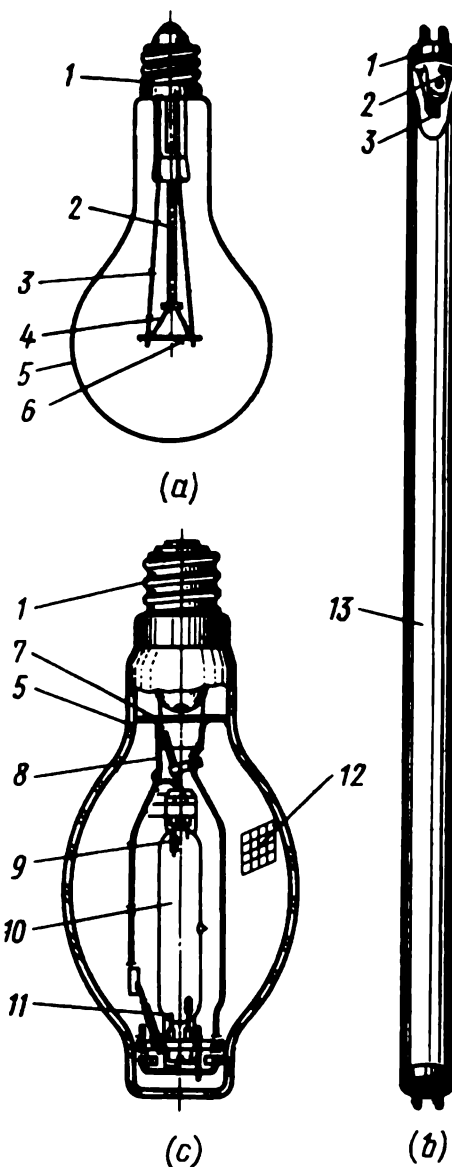


Fig. 29. Electric lamps

a—incandescent lamp; b—low-pressure fluorescent lamp; c—high-pressure mercury-vapour lamp; 1—base; 2—pin; 3—electrode; 4—hook; 5—bulb; 6—filament; 7—ring; 8—resistor; 9—main electrode; 10—crystal heater; 11—auxiliary electrode; 12—phosphor; 13—glass tube

vapour lamps (ДРЛ) available of a two-electrode and a four-electrode modification.

A four-electrode mercury-vapour lamp (Fig. 29c) consists of a threaded base 1, a bulb 5, and a crystal heater 10. The heater contains a metered drop of mercury and the inert gas argon; soldered to the heater leads are electron-emitting tungsten electrodes (main ones 9 and auxiliary electrodes 11). The bulb interior is covered with a thin coat of phosphor.

Supplying voltage to the lamp electrodes causes an electrical discharge in mercury vapours at a pressure as high as 6 to 10 atm which is accompanied by an intensive radiation of light whose spectrum does not contain red-orange rays. Such light is not suitable for illumination unless the composition of phosphor coating the bulb interior is appropriately selected to add red-orange to the main flux under the effect of ultraviolet rays of the spectrum. The orange-red colour added to the main flux excites in the human eye the sensation of white light with a light green hue.

Four-electrode lamps ДРЛ, as distinct from two-electrode lamps of the same type, have two auxiliary electrodes connected to the main ones through series resistors. These auxiliary electrodes facilitate firing of the lamp. With voltage applied to the lamp, a glow discharge is set up between the main electrode and the nearest auxiliary electrode, which ionizes the mercury vapours and facilitates the discharge between the main electrodes.

The ДРЛ lamps fitted with a dia 40 mm base are available of 250 to 1,000 W power.

Gas-discharge light sources (fluorescent and mercury-vapour lamps) offer higher economy than incandescent lamps. Their luminous efficiency and service life are much higher than those of incandescent lamps.

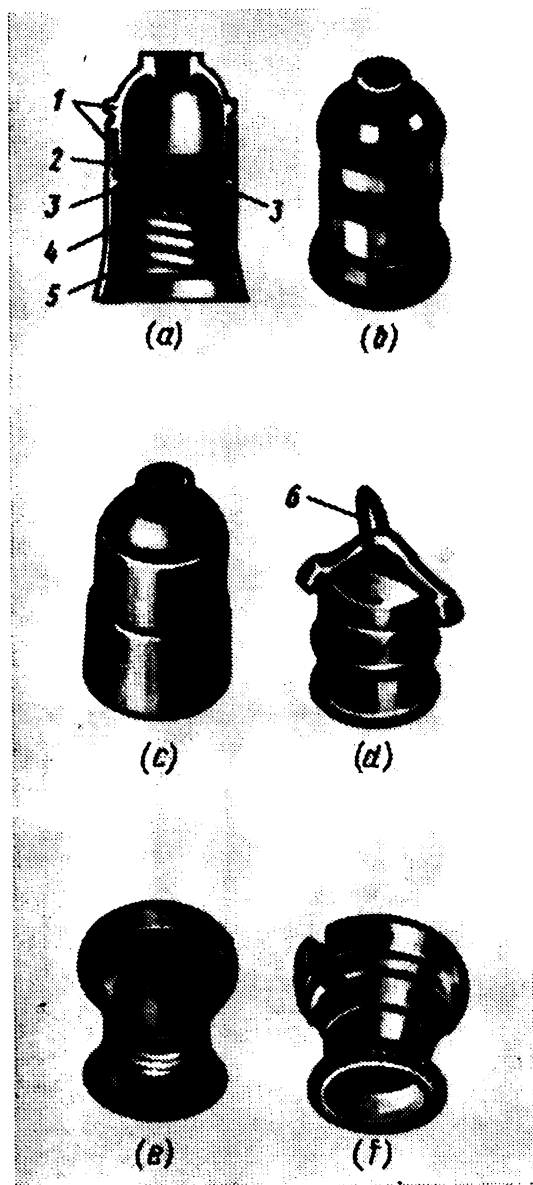


Fig. 30. Lamp holders

a—fitting lamp holder with plastic body; b—fitting lamp holder with brass body; c—fitting lamp holder with porcelain body; d—half-sealed suspension lamp holder; e—ceiling-mounted plastic lamp holder; f—wall-mounted inclined porcelain lamp holder; 1—body; 2—porcelain insert; 3—binding posts for connecting wire leads to the central contact and to the sleeve; 4—central contact; 5—threaded sleeve; 6—steel thimble for suspending the lamp holders

5.2.2. Lighting System Accessories

Lighting system accessories are used to connect the light sources to supply mains, to control them and to maintain desired operating currents and voltages depending on environme-

ntal conditions, such as, industrial conditions, duration of daylight, etc.

Most widely used accessories of lighting systems are lamp holders (Fig. 30), on/off switches (Fig. 31*a, b*), change-over switches (Fig. 31*c*), sockets and plugs, fluorescent lamp starters, etc.

By their mechanical design, application, and method of mounting, lamp holders are grouped into suspension, fitting (with an adapter or an adapter sleeve,

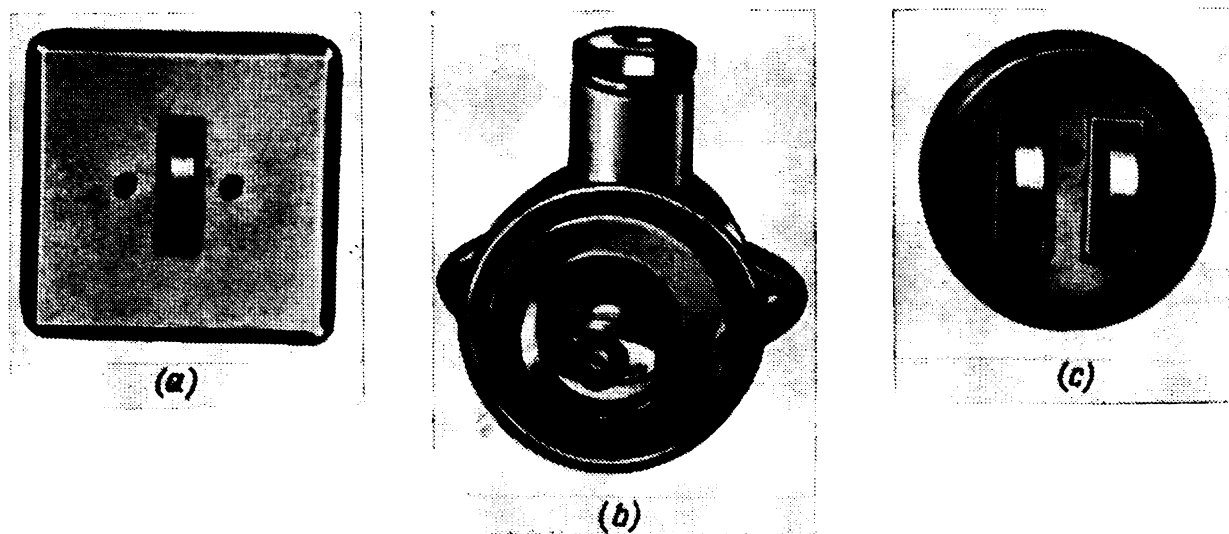


Fig. 31. On/off and change-over switches

a—key-type switch for concealed wiring; *b*—hermetically sealed rotary switch; *c*—change-over switch for concealed wiring

Fig. 30*a, b, c*), half-sealed suspension with a metal thimble (Fig. 30*d*), ceiling (Fig. 30*e*), and wall (Fig. 30*f*) holders. The lamp holders are available with a thread size of 14, 27 and 40 mm to suit the respective lamp bases.

Single-pole on/off switches (Fig. 31*a, b*) and change-over switches (Fig. 31*c*) for up to 250 V and up to 10 A service are designed for switching over electric circuits of lighting systems operating on 50 Hz a.c. supply. Single-pole switches and selector switches coming in protected and hermetically sealed enclosures for open and concealed mounting are rated to sustain at least 20,000 off-operations.

To increase the electrical and mechanical endurance, the contacting elements of modern on/off switches and change-over switches are made of sintered metal, which makes them capable of sustaining more than 200,000 off-operations.

Plug connectors function to connect to supply mains single-phase and three-phase power consumers (portable lamps, domestic appliances, motor-driven tools, etc.) rated at up to 250 and 380 V, 10 and 25 A, respectively.

Plug connectors consist of two basic elements, viz., a socket (Fig. 32*a* through *f*) and a plug (Fig. 32*g* through *j*).

Sockets are available with round (Fig. 32*a, b, c*) and rectangular (Fig. 32*d, e, f*) jacks. Rectangular-jack sockets ensure a more reliable connection, save copper, and their service life is almost twice as long as that of round-jack sockets.

Double-pole (Fig. 32*d, e*) and three-pole (Fig. 32*f*) sockets fitted with an earth terminal are used for connecting portable power consumers to supply mains rated

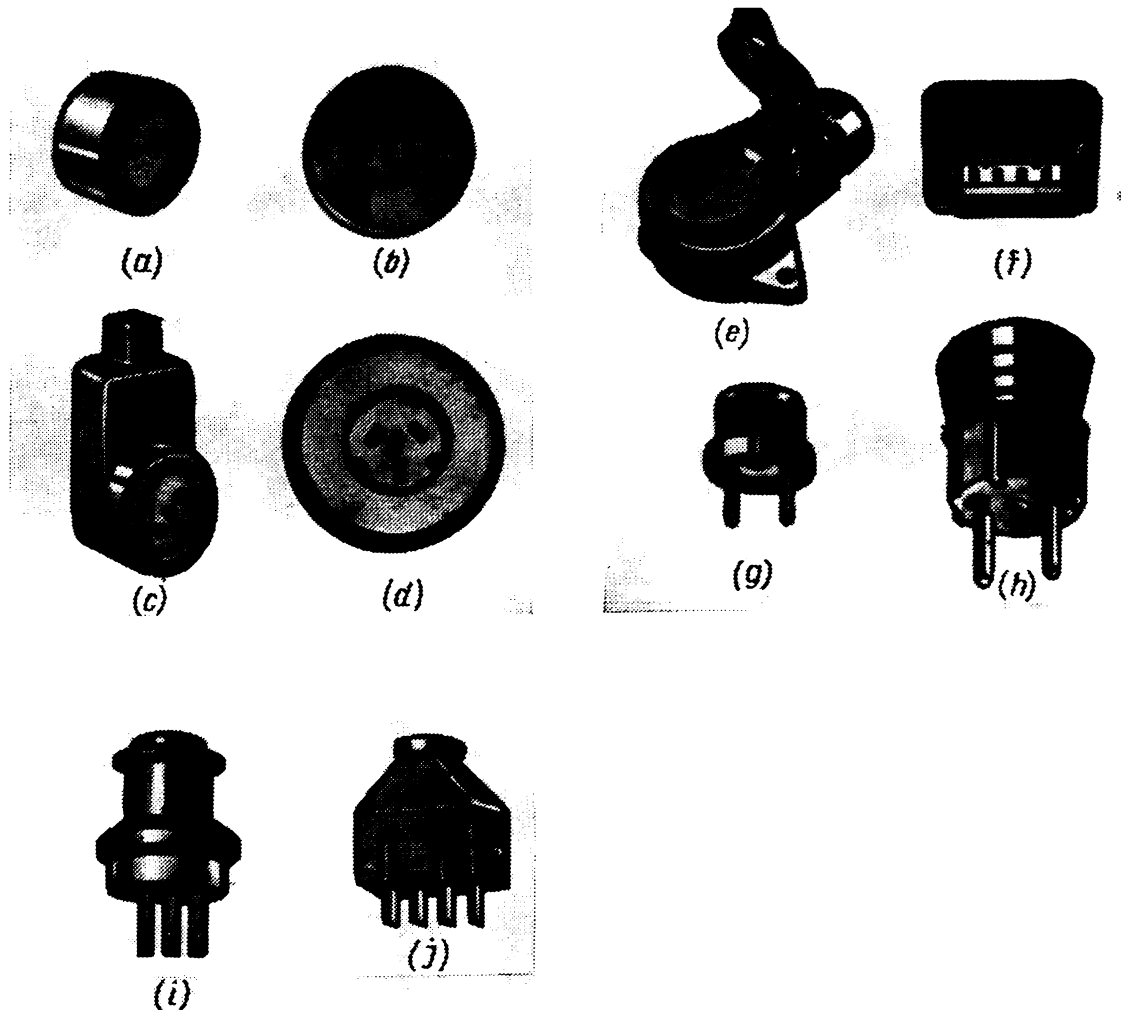


Fig. 32. Elements of plug connections

a—6-A socket outlet for open wiring; *b*—6-A socket outlet for concealed wiring; *c*—socket outlet for sub-skinning mounting; *d*—10-A two-pole socket outlet with rectangular power and earthing contacts for concealed wiring; *e*—10-A two-pole socket outlet with earthing contact, protected type, for open wiring; *f*—25-A, 380-V three-pole socket with earthing jack, protected type, for open wiring; *g*—6-A plug; *h*—10-A plug with earthing contact; *i*—25-A, 380-V two-pole plug with earthing contact; *j*—25-A, 380-V three-pole plug with earthing contact

higher than 36 V in dangerous and extra dangerous locations. The earth terminal of these sockets is connected to the local earthing system.

The terminals of sockets rated up to 10 A are suitable for the connection of conductors having cross-sectional areas up to 2.5 mm². Three-pole sockets rated up to 25 A may be connected to conductors of up to 16 mm² area.

5.2.3. Lighting Fixtures

Lighting fixtures function to illuminate objects, working surfaces, industrial areas, etc., usually spaced not over 25 m from them.

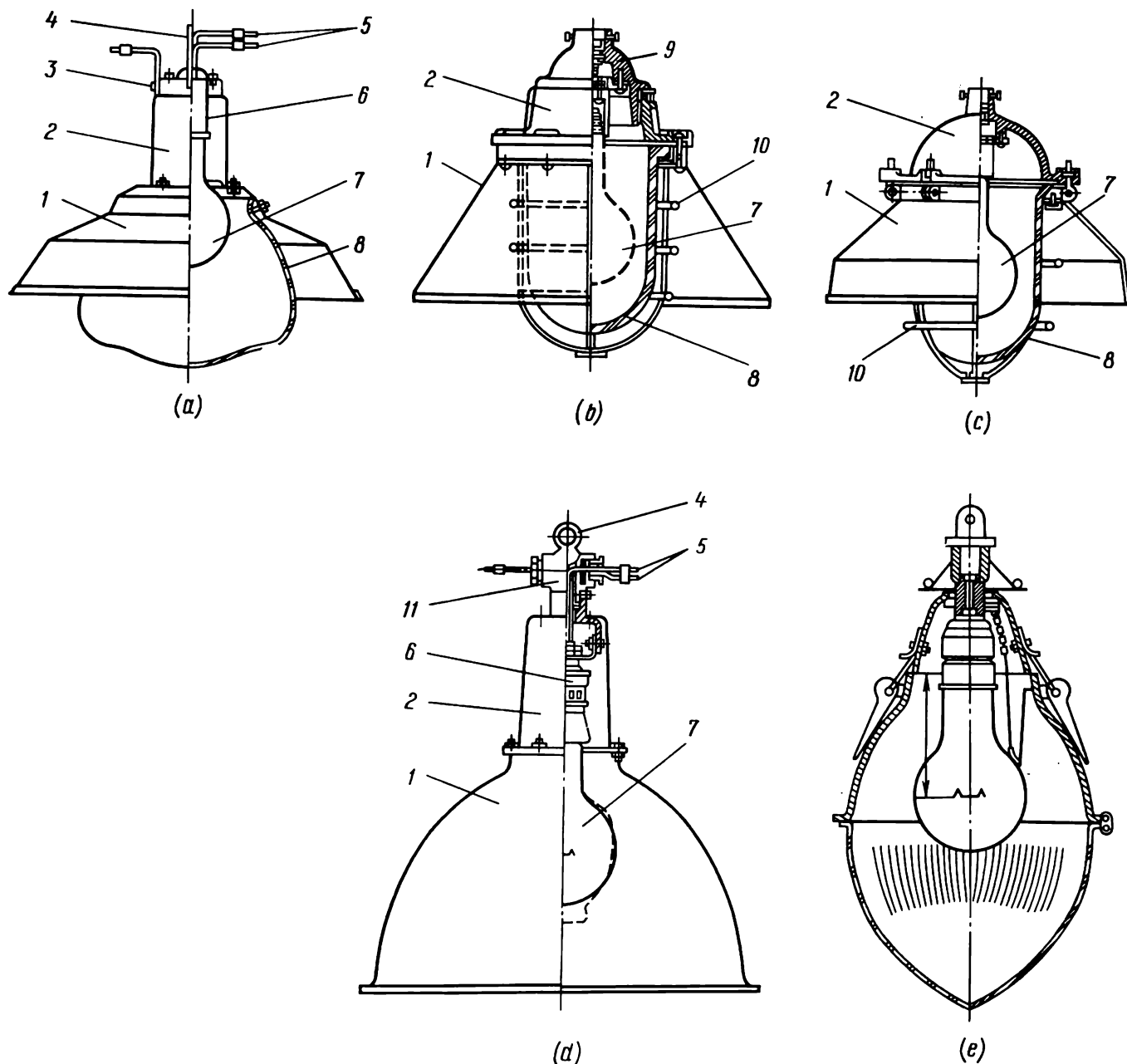


Fig. 33. Lighting fixtures with incandescent and mercury-vapour lamps
a—«Universal»; *b*—mine; *c*—dust-tight; *d*—deep-radiation; *e*—external lighting; 1—reflector; 2—body; 3—earthing bolt; 4—eyebolt; 5—wire lead; 6—lamp holder; 7—lamp; 8—protective glass; 9—cap; 10—guard; 11—shackle

A lighting fixture consists of fittings and a light source. The light source is mounted in the lighting fittings that afford the desired distribution of luminous flux and protect the light source against mechanical damage and environmental effects.

There may be lighting fittings for incandescent and mercury-vapour lamps (Fig. 33*a* through *e*) and those of fluorescent lamps (Fig. 34*a* through *d*).

Fittings for incandescent and mercury-arc lamps consist of a body mounting a lamp holder. The body of enclosed suspension lighting fixtures carries a protective glass at the bottom to protect the lamp against contamination and mechanical damage and an eyebolt on the top for the attachment to a supporting structure. The body neck of heavy lighting fixtures fixed on tubes is made in the form of a pipe union having an internal thread size 3/4 in. Some types of lighting fixtures are

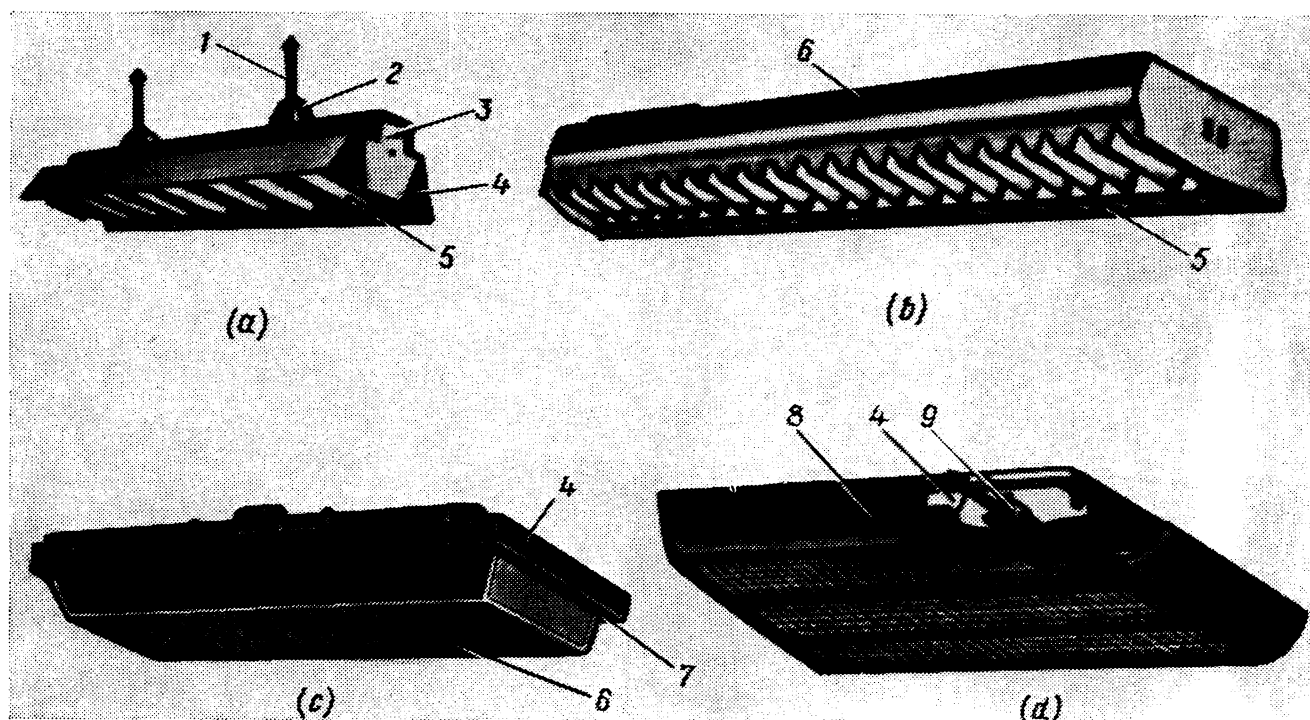


Fig. 34. Lighting fixtures with fluorescent lamps

a—ОДР lamp; *b*—ШЛП lamp; *c*—ВОЛ lamp; *d*—ПБЛ lamp; 1—hanger; 2—hanger cap; 3—trough; 4—reflector; 5—guard; 6—diffuser; 7—supporting frame; 8—hinged frame; 9—attachment fitting

furnished with a special shackle screwed into the pipe union and provided with two stuffing tubes for passing separate supply leads and a hanging hook.

Lighting fixtures feature a great variety of design forms, lighting and electrical characteristics.

Lighting fittings of fluorescent lamps usually consist of a metal trough accommodating starting and control gear, lamp holders, starter holders, and connecting wires.

The lighting fixture is connected to supply mains through binding posts accommodated under one of the hanger caps.

The trough usually carries a reflector and the latter is furnished with a protective screen, glass or diffuser, depending on the type of construction of the lighting fixture.

Table 16

Recommendations for the Selection of Lighting Fixtures to Suit Particular Environmental Conditions

Location according to Regulations for Electrical Installations	Lighting fixture design form
Dry, normal	Arbitrary
Humid	Arbitrary. The lamp holder is to be made of insulating or moisture-resistant materials, such as porcelain, etc.
Extra humid	Splash-proof, water-proof, or sealed. Any design form with lighting fixture elements, including the lamp holder, made of moisture-resistant materials. The inner surfaces of the lighting fixture must be protected against direct ingress of moisture, conductor leads are to be brought in so that any contact between them or with metal fittings is excluded
Hot	Arbitrary, with all structural elements and insulation of conductor leads brought in made of heat-resistant materials
Dusty	Arbitrary, depending on kind of dust and its content in surrounding atmosphere. Open arc design form is not recommended
Chemically active	Same as for extra humid location, but in addition, structural elements of the lighting fixture (including the lamp holder) and the insulation of conductor leads brought in must be resistant to chemically active agents
Fire-hazard: Class II-I Class II-II	Dust-proof or dust-tight (a) Dust-proof or dust-tight depending on amount and type of dust, or fibres contained (b) Where overall air-exchange ventilation and local waste exhaust systems are available: incandescent lamps in any lighting fixture with bulb totally enclosed in silica glass globe; mercury-arc lamps, open-type, with metal screen holding the lamp in position; fluorescent lamps, including open-type, with conductor leads brought in steel pipes or metal jackets, or with lighting fixtures mounted on metal troughs, provided the starting and control gear and the starters are accommodated in a separate compartment of the fixture made of fire-resistant materials, with starters (and lamps, when in storage) reliably held in position
Class II-IIa	Same
Explosion-hazard: Class B-I	Explosion-tight, specified for respective categories and groups of explosive mixtures
Class B-Ia	Any explosion-proof design form specified for respective categories and groups of explosive mixtures
Class B-Ib	Dust-tight
Class B-Id	Any explosion-proof design form specified for respective categories and groups of explosive mixtures (to be mounted directly in explosive locations)
Class B-II	Any explosion-proof design form specified for respective categories and groups of explosive mixtures
Class B-IIa	Dust-tight

The lighting fixtures are manufactured to meet the requirements of operating and environmental conditions as far as their mechanical design, volt-ampere and lighting characteristics are concerned. They must also ensure safety in operation and convenience in maintenance.

For the selection of lighting fixtures refer to recommendations given in Table 16.

A drawback of fluorescent and mercury-vapour lamps, when operated on a.c. circuit, is that the light excites cyclic pulsations at a frequency twice as high as that of supply mains. These cyclic pulsations, though not noticeable by the human eye due to the persistence of vision, are rather dangerous when lamps are used to illuminate moving objects.

Cyclic flickers produce unpleasant stroboscopic effects when moving objects come into the field of view so that the human eye cannot sense the real speed and direction of movement. So, when illuminated by fluorescent or mercury-arc lamps, rotating parts of machines or machined objects moving at a definite speed, may seem to be motionless or even slowly rotating in the opposite direction. For this reason, good practice dictates the operation of fluorescent and mercury-vapour lamps in a manner that will minimize the cyclic flicker.

Circuit arrangements most frequently used for incandescent, fluorescent, and mercury-vapour lamps are discussed below.

5.2.4. Circuit Arrangements for Incandescent Lamps

Lighting systems use a number of circuit arrangements to control incandescent lamps incorporated in them. Two or more incandescent lamps, for example, may be connected to supply mains through one single-pole switch (Fig. 35a).

Five lamps may be controlled by two adjacent single-pole switches (Fig. 35b). One of the switches controls two lamps and the other functions to turn on the remaining three lamps. Such a circuit arrangement is used in large premises where different levels of illumination are required.

Where the number of burning lamps is to be changed at will (as in a candelier), use is made of a candelier switch illustrated by Fig. 35c. As is seen on the diagram, with the switch turned for the first time one lamp comes on. The remaining lamps start burning upon the next turning-on of the switch, but the first lamp goes out. Turning on the switch for the third time lights up all the lamps, and for the fourth time it puts out all the lamps.

If one or more lamps are to be controlled independently from two points, the circuit is arranged with two switches interconnected via two jumpers and a conductor (Fig. 35d). The desired circuits are completed with the aid of the jumpers and the interconnecting conductor. This circuit arrangement is used to illuminate passageways and staircases of dwelling houses and factories, and also to illuminate tunnels having two or more exits.

The lamps of lighting systems supplied with power from three-wire, three-phase supply are connected across the voltage between lines (Fig. 35e); when a four-wire supply system is used, the lamps are connected across the voltage to neutral (Fig. 35f).

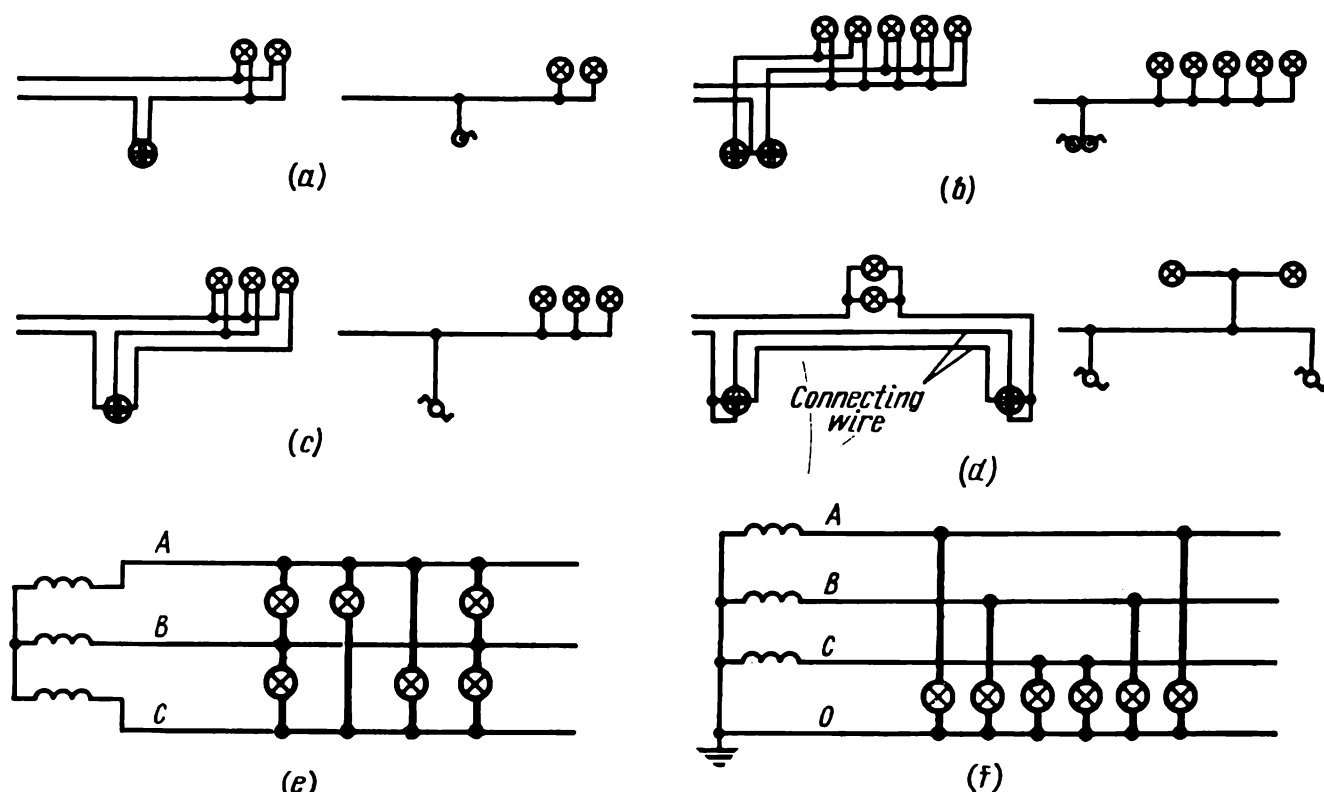


Fig. 35. Circuit arrangements for incandescent lamps

a—with one on/off switch; *b*—with two on/off switches; *c*—with one change-over switch; *d*—with two change-over switches; *e*—across voltage between lines; *f*—across voltage to neutral

5.2.5. Circuit Arrangements for Fluorescent Lamps

Fluorescent lamps are available in the starter-type and instant-starting types.

In starter-type lamps (Fig. 36) a gas-discharge neon lamp with a fixed and a moving electrode functions as a starter.

The fluorescent lamp is connected to supply mains only through a reactance ballast that functions to limit the current through the lamp, thereby protecting the latter against breakdown. A reactance ballast for lamps operating on a.c. supply is a coil with a high inductive reactance, called a reactor.

The fluorescent lamp comes on as follows. A glow discharge is set up between the starter electrodes when the lamp is turned on that heats the movable bimetallic electrode. Upon reaching a certain temperature, the movable electrode of the starter bends up and completes an electric circuit through the fixed electrode. The current flowing through this circuit preheats the lamp electrodes and the latter start emitting electrons. While current flows over the circuit completed by the lamp electrodes, the starter discharge ceases, with the result that the movable electrode of the starter cools down, bends back and opens the lamp circuit thus returning to the initial position. Opening the electrical circuit adds self-inductance emf of the reactor to supply voltage and the surge voltage across the reactor strikes the arc within the lamp and lights it up. With the arc discharge, voltage across the

lamp electrodes and across the starter electrodes, which are in parallel with the former, drops to such an extent that it becomes insufficient to set up a glow discharge between the starter electrodes. The starter electrodes will be connected across the full supply voltage, unless the lamp comes on, and the process will be repeated.

Special starter-type and instant-starting control gear is used for turning on the fluorescent lamp. Starting-and-control gear is essentially a metal-clad control

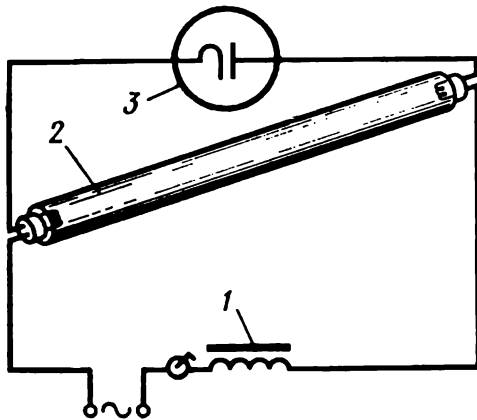


Fig. 36. Circuit arrangement for starter-type fluorescent lamps
1—reactor; 2—lamp; 3—starter

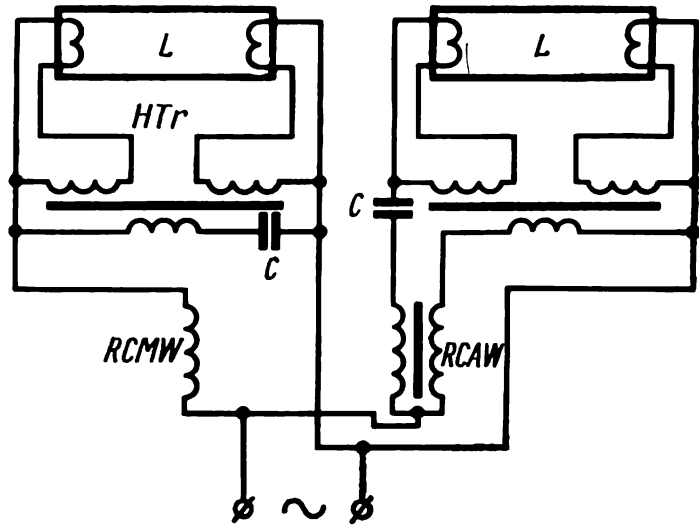


Fig. 37. Circuit-arrangement for instant-starting fluorescent lamps
L—lamp; HTr—heater transformer; C—capacitor;
RCMW—reactance coil main winding; RCAW—reactance coil auxiliary winding

gear that functions to afford a reliable firing and normal operation of lamps, and also to raise their power factor and to minimize cyclic flicker of the lamps. The starting-and-control gears also incorporate anti-interference devices.

Instant-starting gears noted for higher reliability have found a wider application nowadays. Figure 37 illustrates a circuit arrangement for turning on a fluorescent two-lamp fixture using instant-starting control gear.

5.2.6. Circuit Arrangement for Mercury-Vapour Lamps

The ДРЛ mercury-vapour lamps operate on 220 V a.c. supply connected through a firing device that affords a high-voltage pulse (Fig. 38).

The firing device consists of a spark gap *SG*, a selenium rectifier *SR*, a charging resistor *R*, and capacitors *C1*, *C2*. The reactance coil *RC* functions to fire the lamp, to limit current through the lamp, and to regulate its operating voltage and current.

The lamp is fired as follows. When the supply circuit of the lamp is completed, the selenium rectifier *SR* and the charging resistor *R* start passing current and charge the capacitor *C2*. As soon as the capacitor voltage rises to approximately

200 V, the spark gap *SG* breaks down and the capacitor *C2* starts discharging through the reactance coil auxiliary winding *RCAW*, with the result that the main winding *RCMW* is placed at a high voltage whose pulse fires the lamp *L*. Capacitor *C1* functions to protect the rectifier against high-voltage pulses and capacitor *C3*, to suppress radio noise produced by the firing device during its operation.

As distinct from the above-described circuit arrangement for a two-electrode lamp, the four-electrode lamp uses a simplified circuit arrangement dispensing with a firing device.

This circuit incorporates a reactor and a capacitor that perform the same functions as similar elements provided in the circuit illustrated by Fig. 33.

5.3. Circuit Arrangements and Switchgear of Lighting Systems

The lighting systems must:

- (a) incorporate reliable elements ensuring trouble-free operation throughout the entire service period;
- (b) provide for the required level of illumination of premises and working surfaces;
- (c) provide for convenience and safety in maintenance and repairs of instruments, lighting fixtures, and devices.

To meet these requirements, a proper selection of supply circuit arrangements is rather essential.

A number of circuit arrangements will be suitable for use in factory shops where lighting systems are supplied with power from a common transformer incorporated in the factory shop substation and connected into a transformer-main line circuit. If a small number of operating lighting lamps are incorporated in the lighting system, a single-line supply circuit (Fig. 39a) is used. The operating lighting line is connected directly to the switchgear and protective gear cubicle 3. Manual-control switching devices are knife-switches and packet switches. Remote-control devices are contactors and magnetic starters.

A high-power lighting system supplied with power over several main lines may use a circuit arrangement illustrated by Fig. 39b where power supply taken off the cubicle 3 is brought to the main-line board, wherefrom it is distributed to several lines.

In large industrial shops power consumers are fed from a number of built-in transformer substations. With two transformers in use (Fig. 39c), the two lines running from different transformers are isolated by a sectionalizing switch which makes it possible to ensure uninterrupted power supply to lighting and power

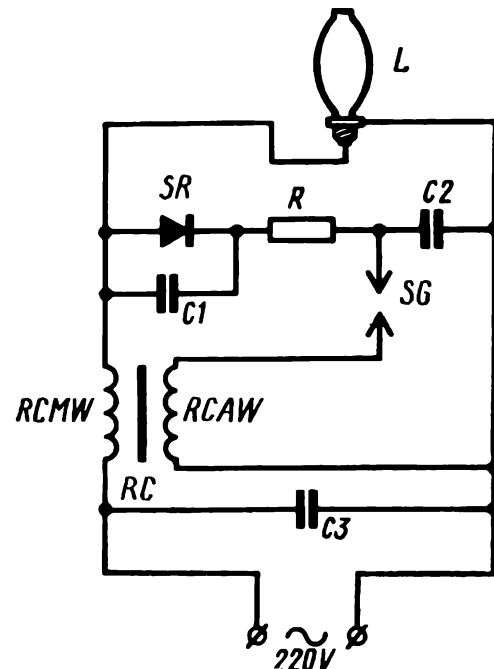


Fig. 38. Circuit arrangement for high-pressure mercury-vapour lamps

L—lamp; *SR*—selenium rectifier (diode); *R*—charging resistor; *C1*, *C2*, *C3*—capacitors; *SG*—spark gap; *RC*—reactance coil; *RCMW*—reactance coil main winding; *RCAW*—reactance coil auxiliary winding

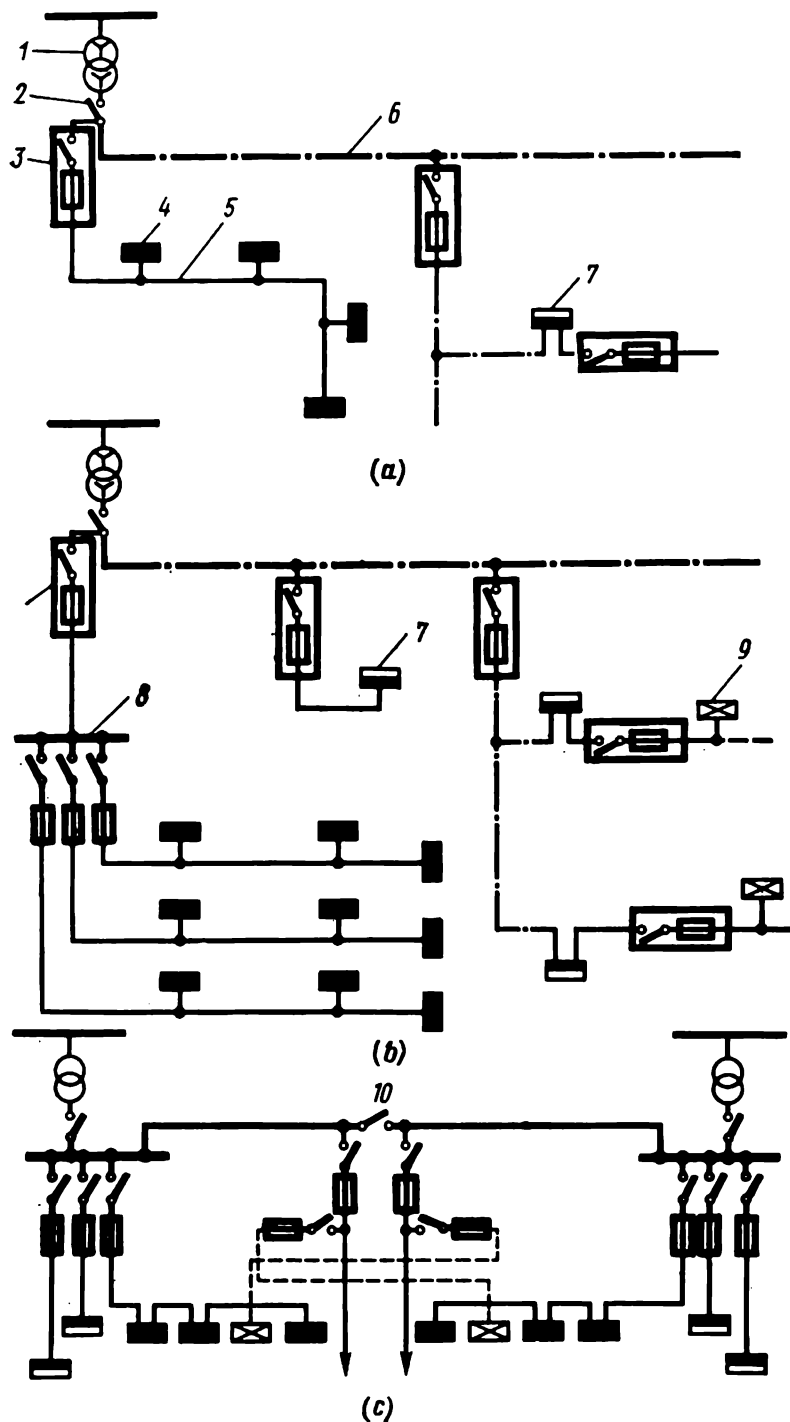


Fig. 39. Supply circuit arrangements for feeding the lighting system over the main line-transformer circuit

a—without main-line distribution board; *b*—with main-line distribution board; *c*—from two transformers; 1—transformer; 2—main circuit breaker; 3—switching and protective gear box; 4—branch-circuit operating lighting board; 5—main-line operating lighting board; 6—main line; 7—power distribution board; 8—main-line board; 9—branch-circuit emergency lighting board; 10—sectionalizing switch (isolator)

loads upon a failure of one of the transformers. With such a circuit arrangement, a stand-by supply is provided for operating lighting and a more flexible operation of emergency lighting is ensured.

The transformer-main line supply circuits are widely used for industrial power consumers due to simple arrangement, high reliability in operation, and minimum quantity of switching and protective devices incorporated.

Lighting systems are furnished with special electrical installations, viz., distribution boards, boxes and service distribution units, intended for the reception and distribution of electric power. These installations incorporate switchgear and protective gear for main and branch-circuit outgoing lines, and also watt-hour meters. Distribution boards of residential lighting systems are shown by Fig. 40 and service distribution units, by Figs. 41 and 42.

The type ПБУ-5 service distribution unit is an enclosed fabricated metal cubicle with a top and a bottom compartment (Fig. 41*a*) accommodating protective gear (circuit breakers АБ-25), circuit-opening devices (circuit breakers А3163), watt-hour meters CA-4, an automatic-control device governing the illumination of entrances and staircases that consists of photoelectric switches ФСК-2 and magnetic starter ПММ-1 (Fig. 41*b*).

The ИВУ-5 service distribution unit is used to receive and distribute lighting and power loads and to meter the electric energy consumed by dwelling houses and public buildings supplied with power over four-wire 380/220 and 220/127 V networks with a solidly earthed neutral.

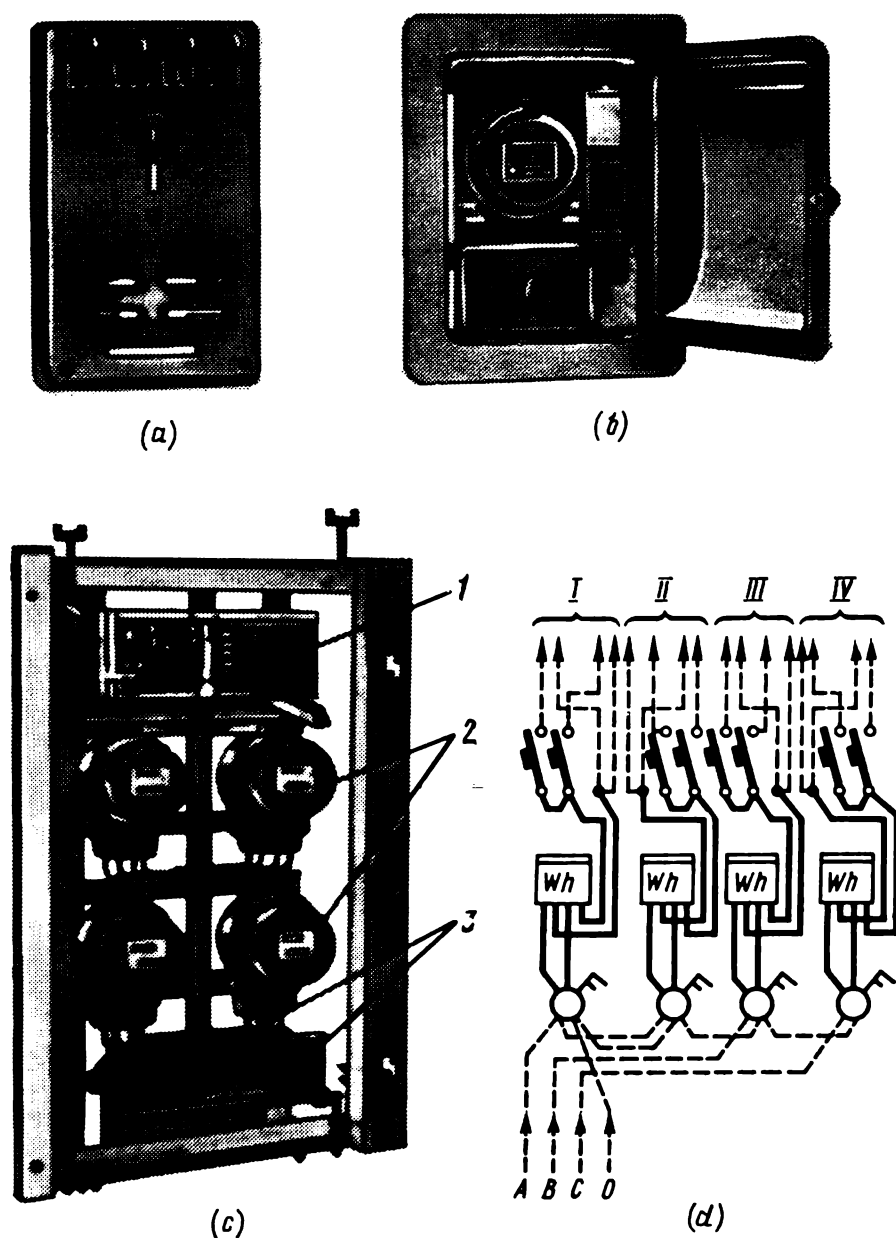
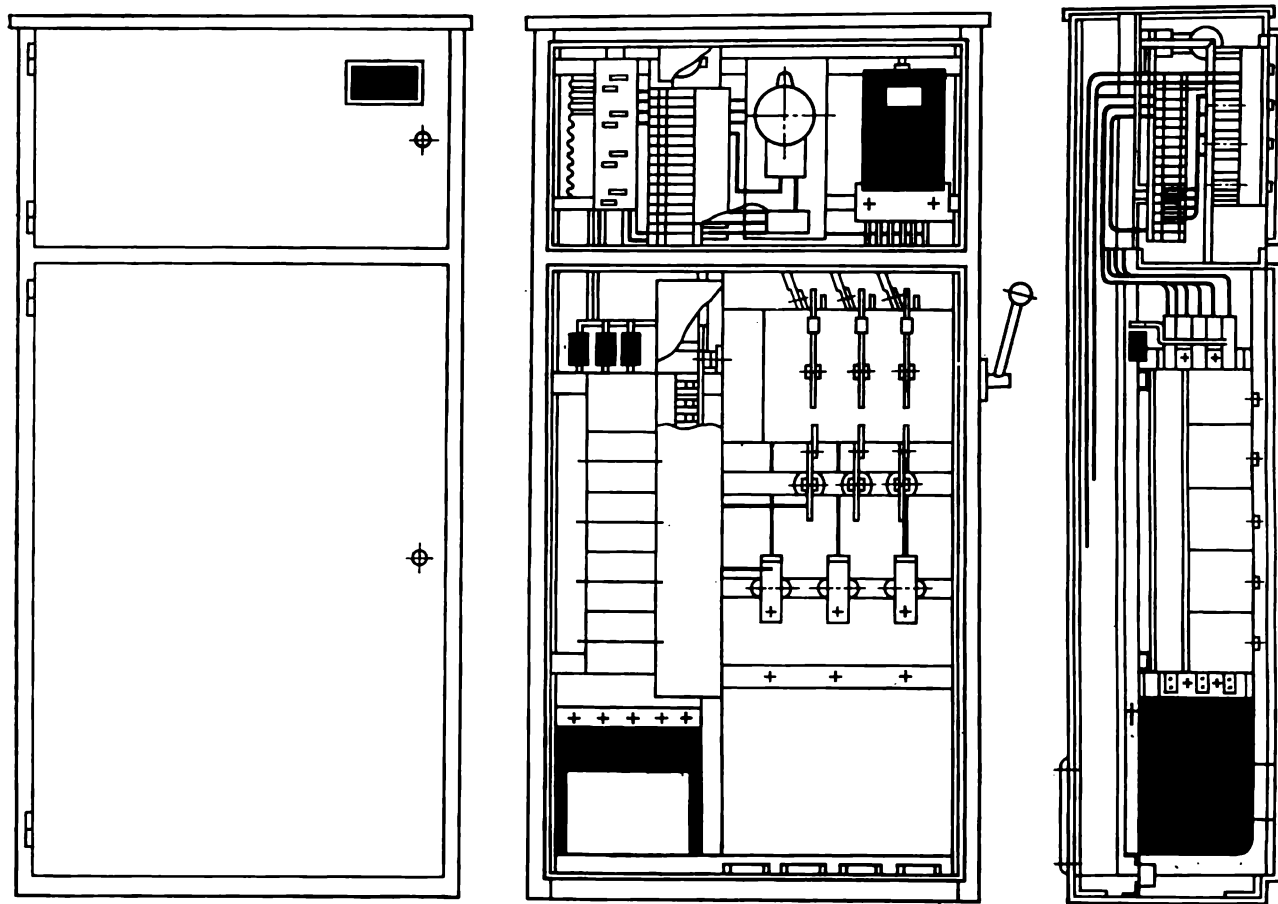


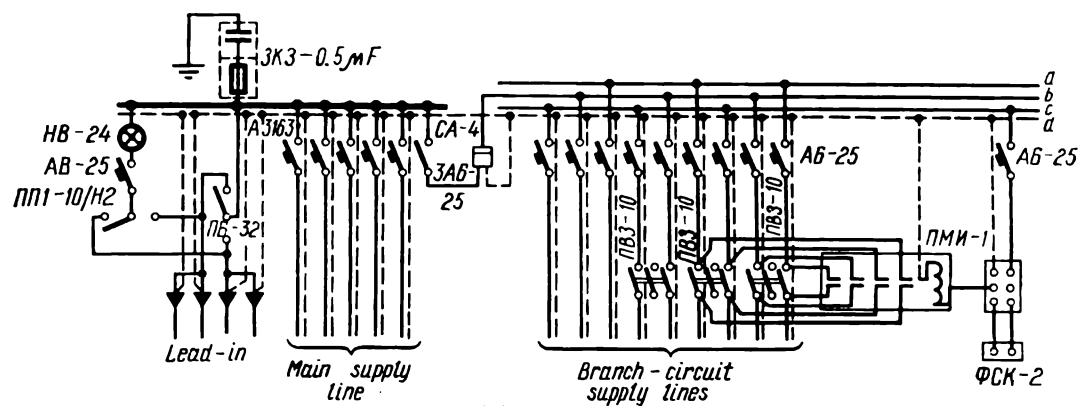
Fig. 40. Distribution boards for residential lighting systems

a—type ИВ, apartment, wall-mounted, two-branch distribution board; *b*—type ИВК, apartment, recess-mounted, two-branch distribution board; *c*—type ИВУ-4 storey distribution board accommodating watt-hour meters (with cover removed); *d*—ИВУ-4 board circuit diagram; 1—circuit breakers; 2—watt-hour meters; 3—packet switches

There is a great number of residential service distribution units (BPC-1, ВУД-5, ВУД-6, ВУД-17, ВУИ-10, ИВ-61, etc.) of different mechanical design and circuit arrangement. They are primarily distinguished by the quantity and make-up



(a)



(b)

Fig. 41. Type ШВУ-5 service distribution unit for residential lighting system
a—general arrangement; b—schematic diagram

of instruments and devices incorporated, rated input current, and characteristics of circuit-opening and protective devices.

Lighting systems of industrial plants and public buildings employ industrial series distribution boards (ОЩБ, ОИБ, etc.) and more intricate service distribution units rated at heavier input currents.

The ОЩБ board (Fig. 42a) is essentially a pendant metal box measuring $500 \times 400 \times 150$ mm. It is fitted with a top and a bottom detachable cover to bring in and out supply and outgoing lines. The detachable chassis accommodated within

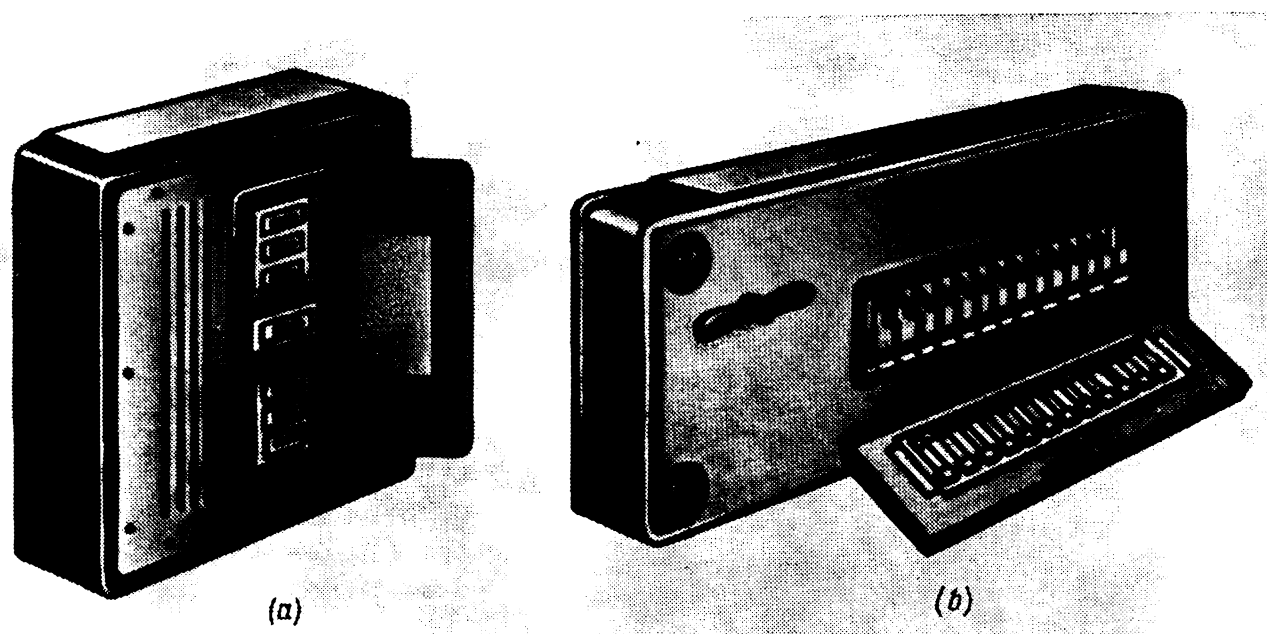


Fig. 42. Commercial distribution boards for industrial and public utility lighting systems
a—ОЩБ; b—ОИБ

the box mounts circuit-opening devices whose handles jut beyond the face panel of the chassis. The box is closed with a door fixed on its front side. The boards are available for six and twelve single-phase branch circuits and incorporate А3163 circuit breakers operating in conjunction with thermal releases rated 15, 20 or 25 A, which are connected to the outgoing lines feeding separate groups of lamps.

The lead-in terminals of the ОЩБ boards are suitable for the connection of conductors having a cross-sectional area up to 50 mm^2 . The terminals for outgoing lines are meant to connect conductors of up to 10 mm^2 area.

The ОИБ board (Fig. 42b) is a metal box measuring $500 \times 260 \times 140$ mm and incorporating АБ-25 circuit breakers and a lead-in packet switch whose handle is brought outside to the face panel of the box. The lead-in terminals are suitable for the connection of conductors having a cross-sectional area up to 50 mm^2 . The terminals of outgoing lines are meant for conductors of up to 6 mm^2 area. The boards are available for six and twelve single-phase branch circuits.

Lighting systems of industrial plants and public buildings make use of service distribution combination switchboards, unit-type distribution centres, and cubicles.

The *IIIK combination switchboard* (Fig. 43a) is essentially a pendant fabricated metal frame mounting boards and devices that serve various purposes. The main advantage of combination switchboards is that any element incorporated in them

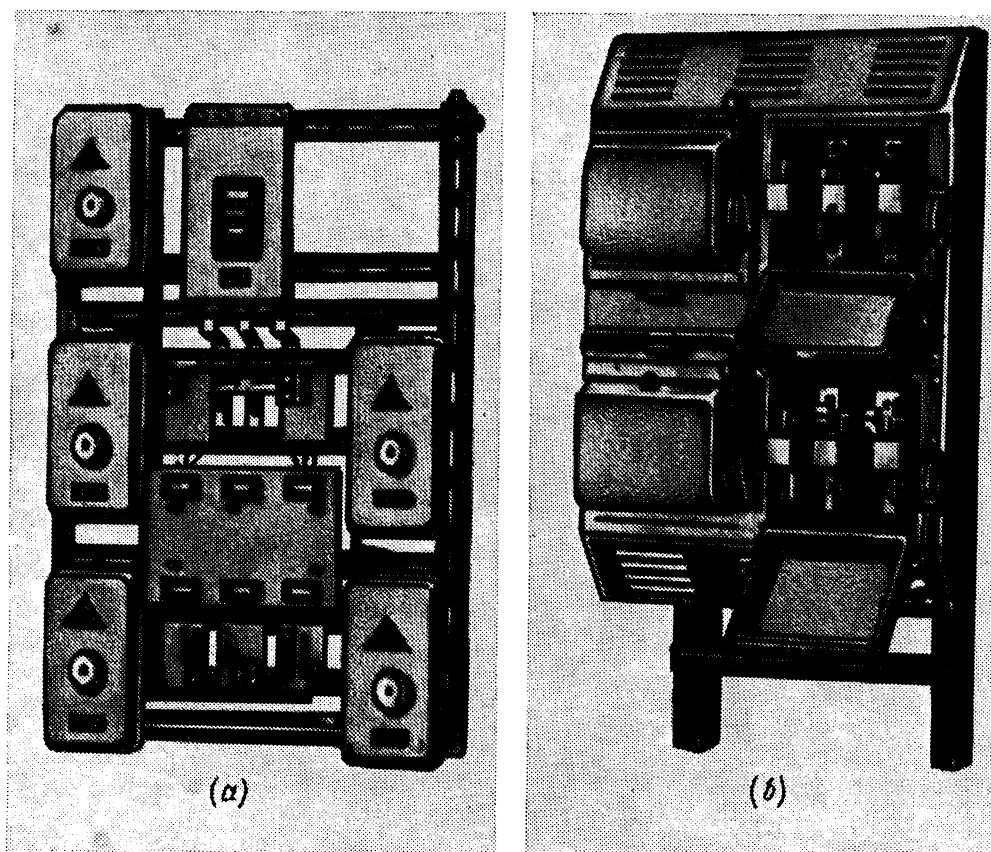


Fig. 43. Distribution boards and distribution centres for industrial lighting systems
a—type IIIK combination board; b—type БПН-4 unit-type distribution centre

can be easily replaced in the event of its failure, or when it is desired to change the supply circuit arrangement of the lighting system.

The *unit-type distribution centre* (Fig. 43b) is assembled of cutout-switch units (БПБ) available for currents of 100, 250, 400, 600, and 1000 A. The cutout-switch unit is a device incorporating ПН-2 cutouts that function both as switching and protective devices. The unit-type distribution centres are easy to operate as they do not contain intricate switching and protective devices; they also ensure safety in maintenance as each unit БПБ is fitted with an interlocking device that makes it impossible to open the door while the handle is in the on-position.

High-power lighting systems of industrial plants are furnished with *enclosed switchgear cubicles* *СII* and *СIIУ* (Fig. 44). The cubicles are made of sheet steel, 1.5

to 2 mm thick. The cubicles accommodate a removable frame mounting a lead-in circuit breaker, fuses of outgoing lines, distribution and feeder busbars. Distribution busbars are supported by insulators and laid horizontally one above the

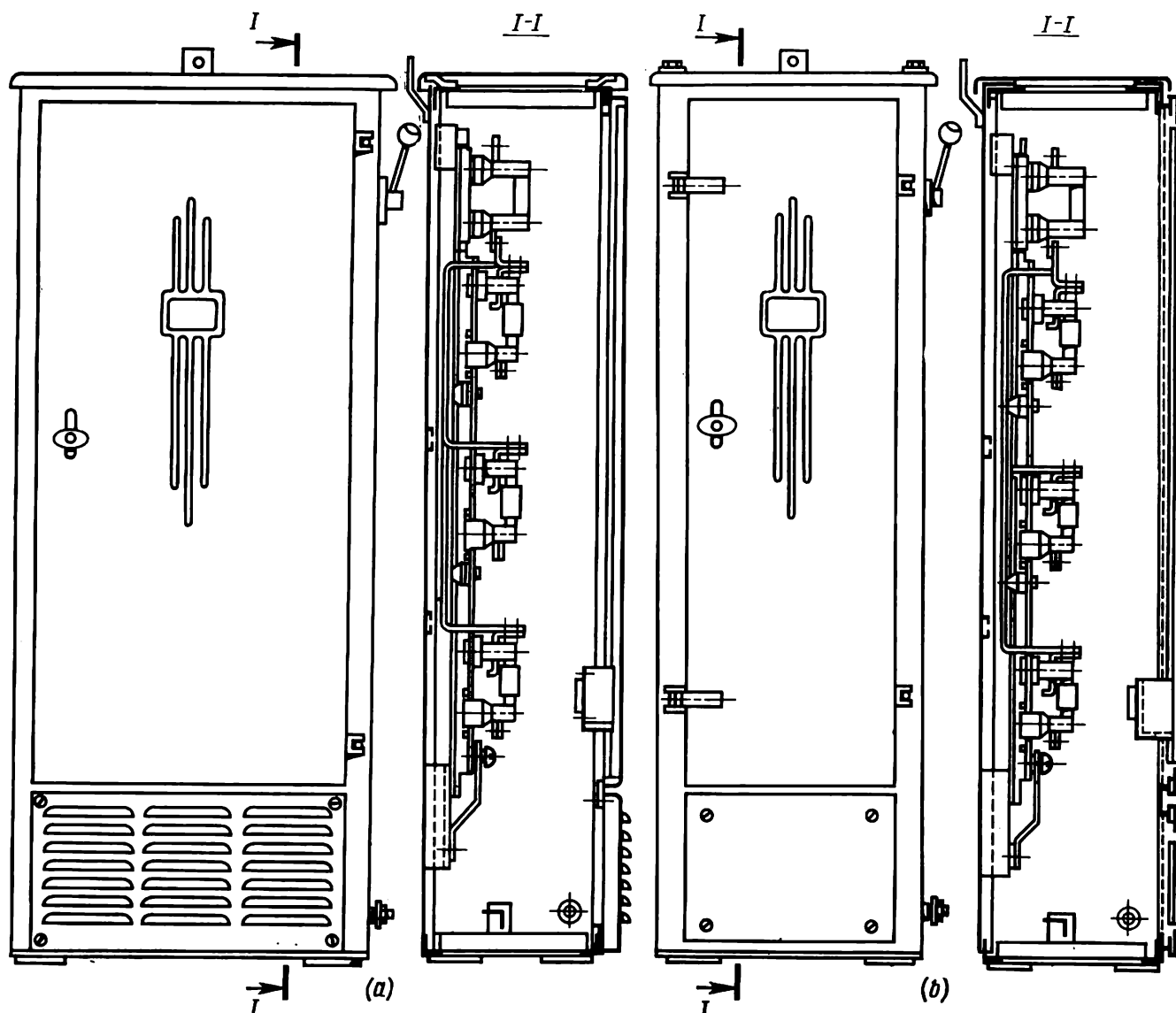


Fig. 44. Switchgear cubicles
a—CH; b—CHV

other. They are connected to the upper contact (binding) posts of fuses protecting one phase lead.

The contact posts are secured to the busbars by means of twin nuts and hold-down washers. Such a fixation makes it possible to tighten up the contact post on the face side of the panel in the course of operation. The lower contact posts of fuses are mounted on insulators which are attached to the cross-pieces of the frame. In this arrangement the fuses of one phase are mounted horizontally. The removable

frame can be taken out of the cubicle to make connections, which greatly facilitates wiring jobs and maintenance operations.

The inner side surfaces of the cubicle carry clips for fixing cables and the rear walls are fitted with shaped structures having special fastenings for the outgoing conductors of fuses. Provided at the bottom of the cubicle are a neutral busbar and a perforated cross-piece used to fix the cables or conductor pipes brought into the cubicle. The CII and CIIY cubicles have a detachable cover which makes it possible to use a press for piercing holes in it, to bring in conductor pipes from the top in the course of wiring.

At the bottom of the face panel there are detachable straps which are removed for the period of wiring to provide easy access for making connections.

The circuit breaker is to be opened or closed by means of a detachable handle brought out through a hole in one of the side walls of the cubicle. The handle is fitted with an interlocking device which makes it impossible to remove the circuit breaker when in the on-position.

As distinct from the CIIY cubicle illustrated by Fig. 44b, the CII cubicle (Fig. 44a) is provided with ventilating louvres on the face side, uses a different method of fastening its covers, its doors are not packed; it can handle higher loads (due to better cooling conditions provided by louvres). It also differs from the former in its overall dimensions.

The rated currents of the CII and CIIY cubicles depend on those of the lead-in circuit-opening devices. The rated currents of the cubicles determine those of protective gear furnished in outgoing lines.

5.4. Marking Out the Paths of Lighting Networks

Marking-out is the initial and most important stage of installation of a lighting system.

Marking-out is meant to determine, with reference to technical documents, the actual path of the wiring system, as well as the layout and mutual arrangement of all the components of the lighting system.

The paths of open wiring systems and basic centre lines for mounting the electrical equipment are marked out according to the finished floor or ceiling marks specified by the project made by builders within the building and according to design distances to trusses, columns, and other building components. The finished floor mark is made on a clean and whitewashed surface in the form of a black line, 10 to 12 mm wide and 120 to 150 mm long.

Marking-out is started with measurements and determination of the wiring system paths with regard to the electrical equipment layout. Thereupon, it is necessary to determine points on the building components to be drilled to make holes for passing pipes, cables, and wires, seats for instruments and devices in the case of concealed wiring, recesses for switch-boards, pits for embedded parts, etc. In the process, places for boxes and fastenings are determined.

Marking dimensions must correspond to those specified by the project or by those given in Tables 17 and 18.

Table 17

**Standard Dimensions in Marking out the Paths
of Wiring System Made of Wires and Nonarmoured Cables**

Description	Conductor sectional area, mm ²	Standard dimensions, cm
Wiring systems on insulating supports		
Maximum distances between points of wire fixation: on insulators, indoors	Up to 10 16-25 35-70 95-240	200 250 300 600
on insulators, outdoors	All areas	200
on insulators between trusses, columns, with copper conductors	Up to 2.5 4 6 and larger	600 1200 1200 to 2500
on insulators between trusses, columns, with aluminium conductors	4-6 10 16 and larger	600 1200 1200 to 2500
Minimum spacings between centre lines in routing: on cleats	Up to 10 16-50 70-95 120	3.5 5 7 10
on insulators	Up to 25 35-50 70-120	7 10 15
Spacings between conductors and surfaces of walls and intermediate floors	All areas	Minimum 1
Elevation of wiring from floor level in normal locations	—	Minimum 200
Same in other locations	—	Minimum 250
Mechanical protection clearance between vertical con- ductors and floor or maintenance area of industrial premises	—	Minimum 150
Bending radius of conductors	—	At least three-fold outer diameter of conductor
Electric wiring system made of wires and nonarmoured cables		
Spacings between fastenings: horizontal wiring	Up to 4 Over 4	Max. 50 100
vertical wiring	Up to 4 Over 4	70 100
Distance from first fastening points to boxes, devices, and passages	Up to 4 Over 4	70 100
Distance from bends to first fastenings	—	Bending radius plus 1 cm from point of inter- section of the route axes
Minimum permissible bending radii for shielded cables BPT, HPT	—	Ten-fold outer dia- meter of cable
Same for TTPΦ wires	—	Six-fold outer dia- meter of wire sheath

Table 18

**Standard Dimensions for Marking out Wiring Systems Routed
in Steel and Insulating Pipes**

Description	Pipe size, in	Standard dimensions, cm
Wiring systems in steel pipes		
Maximum spacing between fastening points of open-wiring pipes on horizontal and vertical sections of the path	Up to $\frac{3}{4}$	250
	Up to $1\frac{1}{2}$	300
	2 and larger	350-400
Distance between the axes of parallel pipes	Up to 1	5.5
	Up to $1\frac{1}{2}$	10
	2 and $2\frac{1}{2}$	14
	3 and larger	16
Same for thin-walled electrically welded pipes joined together with collars	All diameters	10
Distance from fastening points of pipes to electrical devices	Same	80
Same to jointing sleeves, draw-in boxes, and lighting fixtures	Same	30
Angles of bend of pipes and standard elbows	Same	Up to 105, 120, 135, 150
Minimum bending radius of pipes: for all types of open and concealed wiring systems with unserved lead	Same	Ten-fold outer diameter
or PVC sheathed cables laid in concrete and in pipes for miscellaneous concealed wiring systems	Same	Six-fold outer diameter
for open wiring systems	Up to $2\frac{1}{2}$	Four-fold outer diameter
Wiring systems in plastic pipes		
Maximum bending radius of semihard rubber pipes	All diameters	Ten-fold outer diameter
Same of paper-metal pipes	Same	Six-fold outer diameter
Same of plastic pipes	Same	Same
Maximum spacing between boxes: on straight section of path	—	1000
at single bend	—	700
at two bends	—	500
at four bends	—	300
Clearances between wiring elements and various pipelines		
Minimum clearances at points where wires cross: pipelines of combustible fluids	—	10
pipelines of miscellaneous fluids	—	5
Minimum clearances between wires and parallel-running pipelines: of combustible fluids	—	25
of miscellaneous fluids	—	10

The paths of open wiring systems are marked out by means of a string rubbed with blue or dry ochre. The string is used to beat off horizontal and vertical lines, taking care to keep them parallel to the mating lines of the building components.

On the lines thus made the location points of supporting structures and fastenings are to be marked out by lateral lines first at the boxes and then at the power consumers, turns, passages, and then at the intermediate fastenings.

Passages through building components must be arranged on the same line and in the same plane as the cables and wires being routed. Conductors and pipes of open wiring systems must be routed over most inconspicuous places so as not to spoil the interior appearance of premises. The wiring must be routed along cornices and architectural lines and spaced at least 25 mm from them.

Concealed wiring paths routed in grooves and raceways of building components are marked out so as to ensure the minimum possible distance between the electrical system components.

Prefabrication that has found ever growing application in modern building practice makes it possible to dispense with the marking-out stage. Since prefabricated building components are delivered with already finished channels to receive cables, and with pits and recesses ready to mount electrical equipment in them, marking-out is reduced to checking the channels, pits, and recesses made in the building components for compliance with the project and for their suitability to receive electric wiring elements and pieces of equipment.

Industrialized building methods widely used nowadays on large building sites involve a high degree of prefabrication. Separate components of an electrical installation are prefabricated beyond the assembly region (by special factories or preassembly divisions) on process lines employing various mechanisms. These components arrive at the installation site in a maximum readiness condition.

Industrialization of electrical work ensures:

- (a) prefabrication of electrical installation components and pieces of electrical equipment irrespective of the state of construction work;
- (b) use of high-output special-purpose or multipurpose mechanisms;
- (c) organization of work on process lines;
- (d) minimum number of manual operations on site of installation;
- (e) high labour productivity of electricians;
- (f) short time and high quality of work.

When prefabricated elements of electrical networks are used, pieces of electrical equipment and supporting structures to be installed are coordinated on the reference drawings with the reference marks of building components. The reference drawings illustrate dimensional diagrams of wiring system paths and cable lines. Electrical networks must also be coordinated with the reference marks and pieces of electrical equipment so that the drawings illustrate not only the direction and location of paths and network sections but also their actual length.

Where intricate electrical installations are to be mounted, the project includes, apart from dimensional diagrams, cable and pipe assembly lists and logs giving specifications of electrical network components.

If the project does not contain the required data, electrical network components can be prefabricated on the basis of preliminary measurements made after

marking out the wiring paths and location points of electrical equipment.

Measurements are taken by special personnel and electricians using instruments and tools (Fig. 45) applied for marking-out operations. Measurements are required to specify more accurately the wiring paths and electrical network routes to installed electrical equipment and switchgear, these measurements being coordinated with building geometry, axes, finished floor marks, and other reference marks. Particular attention is to be given to the correct marking of bending angles

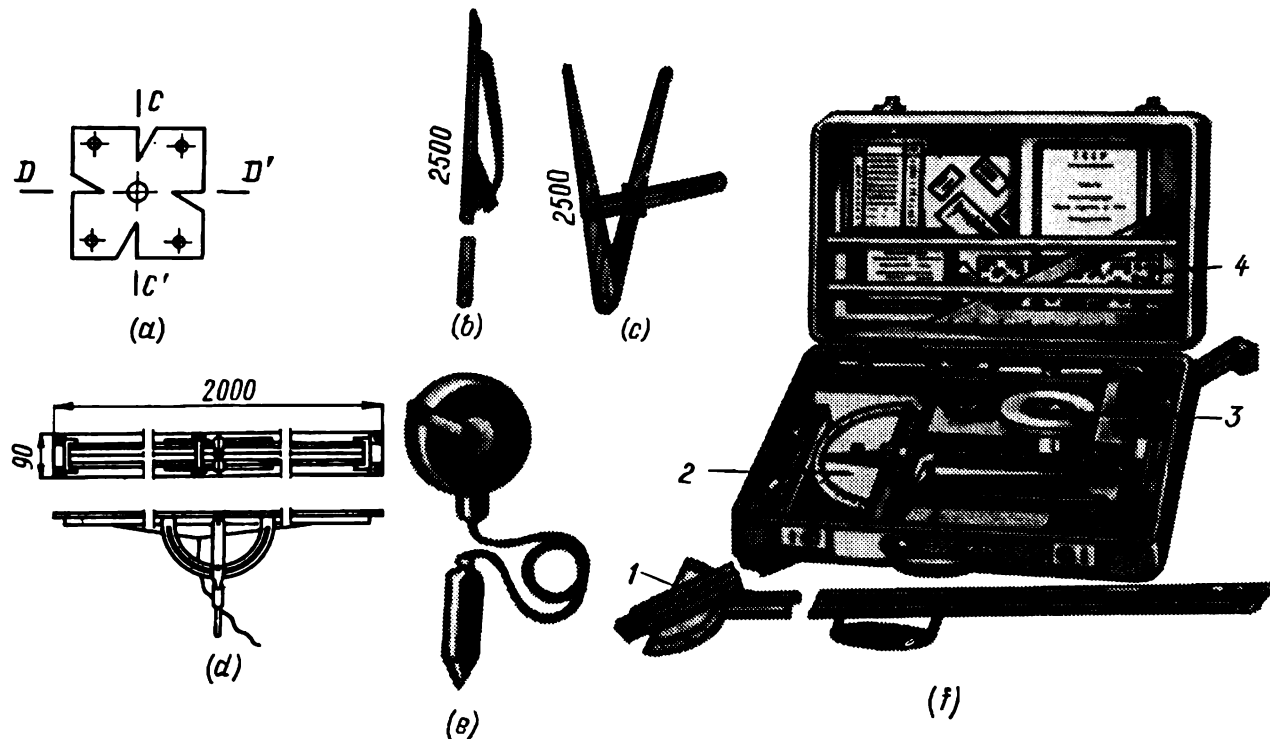


Fig. 45. Marking-out tools and accessories

a—template; *b*—marking-out stick; *c*—wooden calipers; *d*—marking-out frame with pole; *e*—plumb bob with cord; *f*—marking-out tool kit; 1—extensible straight-edge; 2—goniometer; 3—measuring tape; 4—marking-out stencil

at turns and at points where the electric circuits pass to different positions in space, taking into account the standard angles of turn and bending radii specified by Tables 17 and 18.

Proceeding from the measurements taken, the measuring personnel draw sketches of parts to be prefabricated for intricate network sections or compile assembly lists for simple parts. These sketches or lists are then delivered to the preassembly division where they are used to prefabricate the required elements and parts of electrical networks.

The sketches, assembly lists, and reference documents contain all necessary technical data on electrical networks to be installed.

Circuit components are illustrated on sketches by conventional symbols.

Two-dimensional drawings are made to illustrate parts to be prefabricated for simple wiring systems, and three-dimensional drawings to show those for more

complex systems. To facilitate drawing sketches use is made of specially printed forms with a two-dimensional or three-dimensional coordinate scale.

Figures 46 and 47 illustrate dimensional drawings of wiring and intricate pipe distribution systems.

The dimensional drawings of wiring systems (Fig. 46a, b) show:

(a) type, cross-sectional area, and number of wire or cable conductors;

(b) methods of connection of separate prefabricated parts and jointing or splicing (by soldering, welding, compression, etc.);

(c) methods of terminating the conductor leads to be connected to lighting fixtures, instruments, and appliances with a lug, thimble, or shoe, its type being indicated;

(d) identification colouring of phase wires and conductor leads;

(e) total length and dimensions of separate sections of the wiring system, points of splicing and location of splice sleeves;

(f) length of branch sections running to lighting fixtures and appliances, elevation and type of lighting fixture.

In measuring and drawing catenary wiring systems (Fig. 46c) the sketches include in addition the design type and diameter of catenary cable or wire, type and cross-sectional area of wires and cables, methods of conductor attachment to catenary (by cleats, clips, supporting structures, etc.), types of dead-end clamping devices and auxiliary catenary suspensions and anchor wires, spacings between suspensions and anchor wires, methods of earthing and of earthing device connection to the overall earthing system.

Dimensional drawings of measured cable lengths (Fig. 46d) show the design types and sectional areas, types of terminations and connectors, methods of termina-

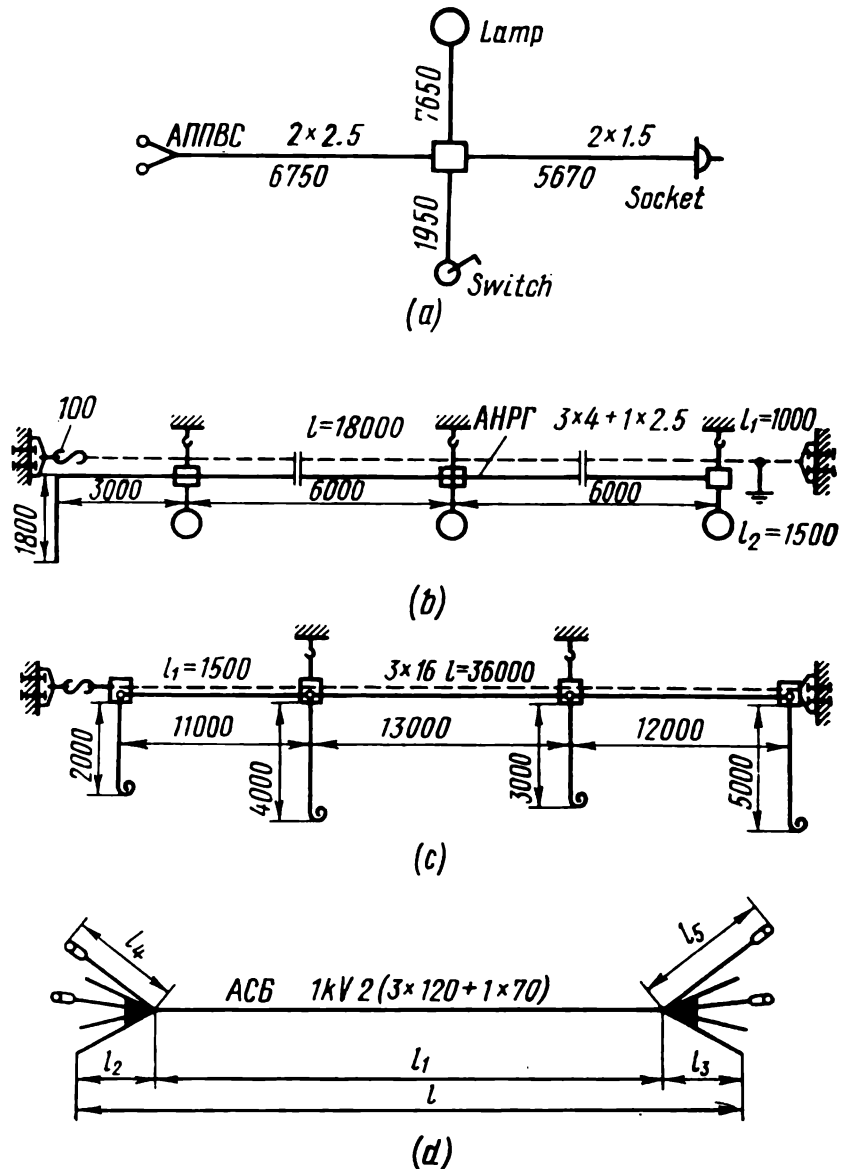


Fig. 46. Drawing dimensional sketches for lighting wiring systems

a—AIIIHC wire; b—AHPT cable; c—ATF wire; d—cable line section

tion of conductor leads and types of cable lugs, identification colouring of conductors and marking of cable lengths used in the drawing, size of each cable length, spacing between connectors, lengths of terminations and leads, types of supporting structures and methods of attachment of cables on them.

Dimensional drawings of wiring conduits are made taking into consideration standard prefabricated parts and elements manufactured to comply with design data obtained from albums appended to the standard project for conduit wiring systems. Prefabricated standard parts and elements include: standard straight pipe lengths (10 to 600 cm), pipe lengths bent at standard angles (90, 105, 120, 135, and

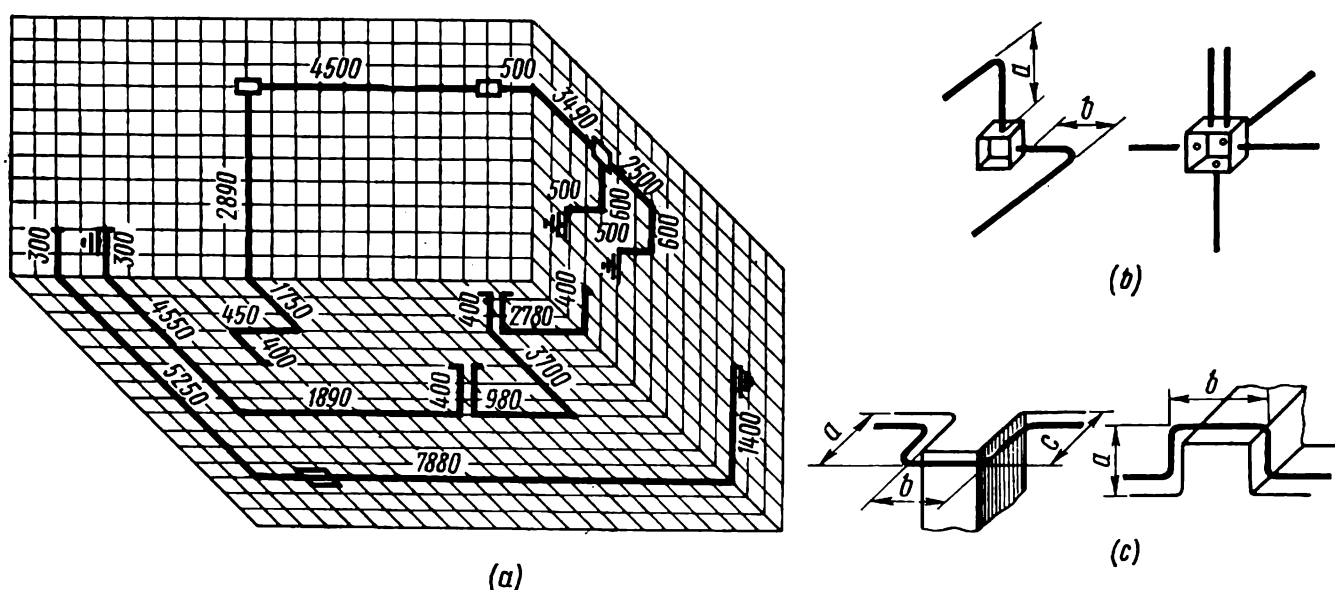


Fig. 47. Drawing dimensional sketches for preassembling intricate conduits or pipelines
a—three-dimensional representation of pipe distribution; *b*—pipe exits from the boxes; *c*—pipes laid around protruding building components

150 deg) with bending radii of 400 and 800 mm, elbow pipes, alternate route pipes, cleats, straight and bent pipe stacks and blocks, miscellaneous standard elements of prefabricated parts.

When standard parts and elements are used for prefabrication of a wiring conduit, the operation is reduced to the selection and assembly of desired standard components to comply with the dimensional drawing submitted.

For simple pipe lines and distribution assemblies, reference documents and dimensional drawings are compiled to include:

- (a) material and size of pipes for conduits to be prefabricated;
- (b) total number of pipe stacks and blocks and number of pipes per stack and block;
- (c) types, location, and number of branch and draw-in boxes;
- (d) methods of connection of pipes to each other and to the boxes (by threaded connectors, by welding, etc.);
- (e) mutual position and direction of pipes, stacks, and blocks;

- (f) points and methods of crossing of expansion joints of building components;
- (g) points and methods of connection of conduits to earthing systems;
- (h) identification colouring and marking of prefabricated pipes adopted.

For intricate pipe lines and distribution assemblies three-dimensional drawings are made (Fig. 47a, b, c).

The order for prefabrication of wiring parts and components, cable lengths, and conduits shall be accompanied by the list of parts to be prefabricated where, in addition to data on how to manufacture the required parts and assemblies, it is necessary to indicate methods of their assembly, packing, and transportation.

5.5. Preassembly of Lighting Wiring Elements

Wiring elements of a lighting system are preassembled at the preassembly division on stands, laying-out tables, and benches (see Fig. 9), forming a process line. The process line is used to make the following operations in processing wires and cables:

- (a) metering conductors and cutting them to desired lengths;
- (b) stripping insulation off the conductor leads;
- (c) finishing the bare leads for making connections or for splicing, for connecting them to lighting fixtures and various devices;
- (d) jointing and splicing wires and cable conductors by compression, soldering, or welding;
- (e) insulating bare portions of joints and splices;
- (f) checking and marking circuit components.

In the case of a large scope of preassembly work, conductors of sectional areas up to 10 mm² are treated using the KMO-3 line composed of intricate high-output mechanisms, MP-1, MC-2, and C3-3 (see Fig. 10).

Conductors of large sectional areas (16 to 240 mm²) are processed on a KMB-4 line composed of two mechanisms, MPБ (Fig. 11a) and MCB (Fig. 11b).

There are many process lines for processing steel and plastic pipes, copper and aluminium busbars, trolley wires, and the like by means of special-purpose mechanisms. For example, a highly mechanized process line for preassembly of steel conduits with the aid of machines and mechanisms performs the following functions: cuts pipes to desired lengths; taps the pipes at the ends; cleans the pipes by chemical reagents; paints the internal and external surfaces of pipes; bends pipes through standard angles; joins together separate elements of steel conduits by welding or by any other suitable method.

Mechanisms incorporated in a busbar preassembly line perform the following jobs: set the busbars flat or on edge; mark out the points of busbar connections or branches; cut the busbars to desired lengths; drill holes of desired size and in desired quantity in busbars; bend busbars flat, on edge, in a hairpin or helical manner; clean off the contacting surfaces of busbars, etc.; weld busbars together and weld to them strips made of a different material (such as a copper strip to an aluminium busbar that is to be connected to an electrical device with a copper terminal lead); paint the busbars in standard colours to identify phases.

Mechanisms and tools for each process line are selected individually depending primarily on the scope of electrical work to be done, availability of mechanisms and their capacity, economic considerations as to whether it is reasonable to mechanize this or that process.

Preambly of pipes, wires, cables, busbars, wiring systems, and miscellaneous elements of electrical installations beyond the installation site is an advanced installation and wiring technique on condition that a centralized supply of all required materials directly to the preassembly division is ensured. Where the installation contractor is supplied with required materials and pieces of electrical equipment by the customer, it is good practice to make most simple jobs on site if intricate mechanisms are not required for their performance. This will save time and money as there is no necessity in sending the materials to the preassembly division and delivering the assembled pieces back to the installation site.

Industrialized preassembly of all the elements of electrical installations is now widely used by many large electrical installation organizations.

5.6. Installation of Open Lighting Wiring Systems

Open wiring systems are those routed over the surfaces of building components (walls, ceilings, columns, trusses, etc.) directly on insulating supports or in pipes (steel, plastic, etc.).

5.6.1. Routing Open Wires Directly Over the Surfaces of Building Components

The type ППБ (АППБ) PVC covered wires, ТППФ (АТППФ) wires covered with a thin metal sheath, and rubber covered cables БПГ (АБПГ), ГПГ (АГПГ) are suitable for open wiring routed over the surfaces of building components.

The regulations for electrical installations specify laying the ППБ and АППБ wires over plastered or plaster-board-surfaced walls, partitions, and ceilings, and also over fire-resistant walls and partitions in dry premises at a supply voltage of maximum 380 V.

The wires are arranged in parallel or normal to the building and architectural lines of premises. When a number of wire lines are laid in parallel, they must be spaced at least 3 mm apart.

When installed on wooden surfaces, the ППБ and АППБ wires are to be fixed on straight sections of the route with the aid of nails spaced 200 to 250 mm apart (Fig. 48a), with asbestos sheets placed under the wire, the sheet protruding 3 or 4 mm from under the wire either side. The wires laid on concrete surfaces are to be secured with clasp-terminated strips (Fig. 48b). Nails are to be driven in strictly along the centre line of the film separating the conductors. At first three fourths of the nail length are to be driven, the remaining portion being rammed through a mandrel attached to the nail head. The mandrel prevents damage to the wire by the hammer. Wire crossings shall be avoided. Obstacles on concrete and brick components are to be by-passed in open plastered channels. Wire crossings on wooden surfaces are to be additionally insulated with two or three layers of insulating tape.

The ППБ (АППБ) wire portions to be brought into a box (Fig. 48c) or bent on edge at right angles (Fig. 48d) shall be cleaned of the conductor separating film.

In passing from one floor to another, the ППБ (АППБ) wire is to be run in a steel pipe at least 2 m from the intermediate floor to protect it against mechanical damage.

The recent practice in common use by electricians nowadays is to fix the ППБ (АППБ) wires by sticking the fastenings directly to the surfaces of building components (concrete, brick, metal, etc.) with the aid of adhesives.

The type БМК-5К adhesive supplied to installation sites in tubes is used for the purpose.

This method can be used for plastic fastenings weighing not over 200 g and having a flat corrugated bearing surface at least 11 mm thick and at least 6 cm²

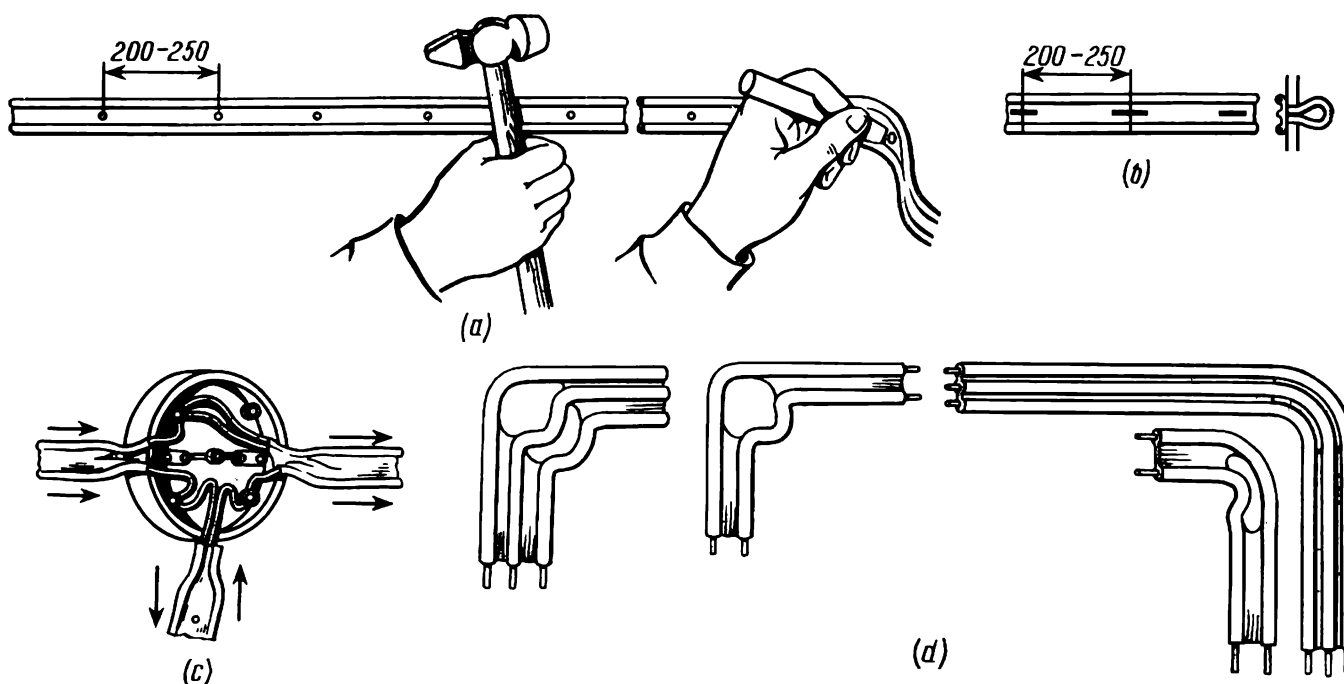


Fig. 48. Elements of open wiring using flat wires ППБ and АППБ
a—fixation with nails; b—fixation with clasps; c—bringing into a box; d—wire bending

in area. Such fastenings can be stuck to concrete, brick, glass, and ceramic building components possessing the required strength.

It is not recommended to attach the wire with adhesive БМК-5К directly to building components because this fast-drying adhesive changes its properties and the wire may adhere to the surface differently at the beginning and end of the wiring system and may come off at one end, with the result that the entire wiring may come loose. For attaching wires with the aid of an adhesive, use is made of plastic hardware only (with the exception of polythene parts) because steel fastenings are easily corroded and aluminium ones do not afford the desired fixation because of poor adhesion to aluminium.

Sticking of hardware is made in two stages, one being preparatory and the other finishing.

Prior to starting the work, the building surfaces are to be thoroughly examined to make sure that they are suitable for the purpose. The surfaces must be robust and even. Hardware must never be attached to moist, oil-treated, whitewashed, painted, or plastered surfaces.

Preparatory work consists in marking out the lines and points of attachment, cleaning off the surfaces to receive hardware to be stuck to them, furnishing the standard equipment required, and degreasing their attaching surfaces with acetone.

The finishing stage includes the following jobs: applying to the surfaces of building components and hardware the appropriate amount of adhesive so as to obtain an even layer of 0.5 to 1 mm; spreading the adhesive over the building component surface and over that of the item to be attached to it with the aid of a spatula, the building component surface covered with adhesive being slightly larger than that of the item to be stuck to it; pressing the item to the building component surface at a light force and keeping it so for 3 to 5 s. This work shall be carried out in premises where the ambient temperature is higher than 0°C. Cables, wires, and other parts may be secured on the hardware attached by an adhesive upon the expiration of 24 hours after sticking.

The БМК-5К adhesive used for sticking electrical hardware

is composed of a resin (basic adhesive agent), porcelain clay (filler), and acetone (solvent). Acetone is an easily inflammable and toxic liquid, and therefore in dealing with the adhesive, appropriate safety precautions must be observed.

The sticking method reduces as much as 70 or 80 per cent of drilling jobs and two or three times raises labour productivity.

Open wiring with the use of metal-sheathed wires ТПФ and АТПФ is suitable for dry heated, hot, and dusty utility and industrial premises where there is danger of mechanical damage to the wires.

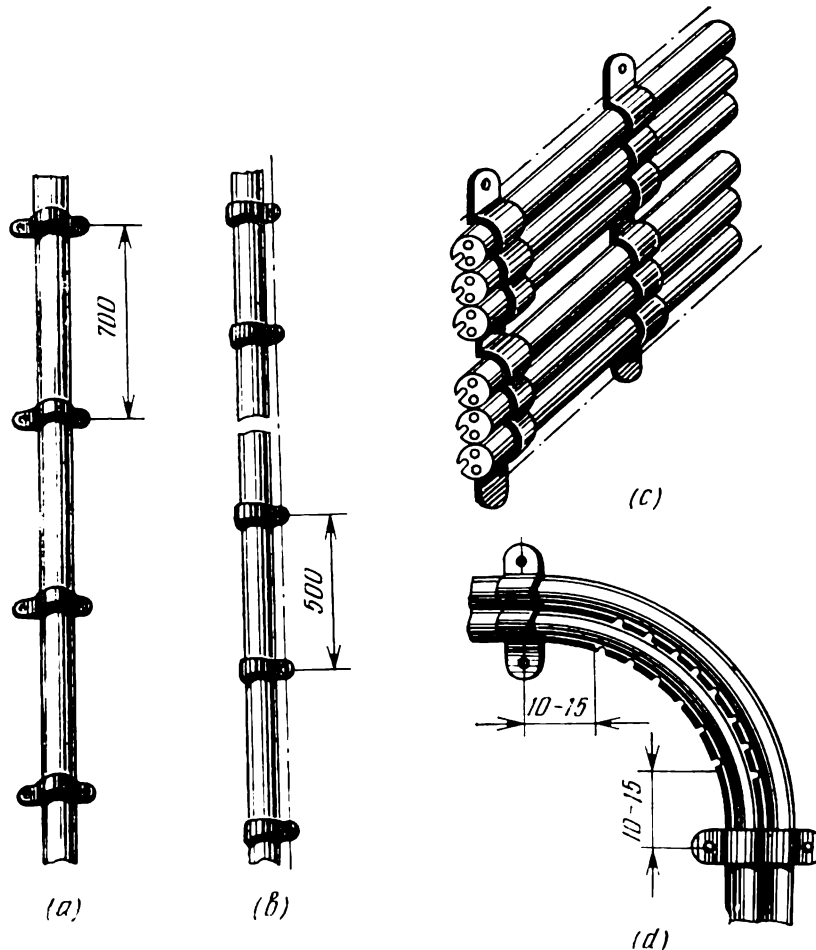


Fig. 49. Fixation of ТПФ and АТПФ wires for open wiring system

a—by two-lug clips when arranged vertically; *b*—by single-lug clips when laid horizontally; *c*—by a single clip for several wires; *d*—bending wires and fitting clips on bent portions

The ТПРФ and АТПРФ tubular metal-sheathed wires are laid in parallel or normal to the architectural lines of the premises and secured in position with standard single- or two-lug clips. Single-lug clips are used to secure single conductors on horizontal portions of the route, with the lug positioned at the bottom. Single-lug clips stamped with a stiffening rib can also be used for fixing wires laid vertically. Clips securing wires of up to 4 mm² area shall be spaced maximum 500 mm with wires mounted horizontally and maximum 700 mm with those laid vertically. Clips for wires of 6 mm² and larger sectional areas may be spaced up to 1000 mm apart. The distance between the clips and boxes, instruments or devices, terminations, or passages shall be 50 to 100 mm. The distance between the starting points of the bent portions of wires and the closest clips shall be not over 15 mm (Fig. 49a through d).

Where tubular aluminium-sheathed wires are to be secured by clips and clasp-terminated strips, these fastenings shall be set on pressboard or any other similar flexible spacers. The spacers must jut beyond the clips or strips at least 1 mm on either side. The spacer elevation for metal-sheathed wires from the floor is not specified.

When installing tubular metal-sheathed wires vertically over walls or horizontally over ceilings, one shall bear in mind that the sheath seam must face the building component surface. The seam of metal-sheathed wires laid horizontally over walls must face the floor

so as to prevent moisture penetration under the sheath.

Clips, boxes, and miscellaneous hardware are to be fixed to brick, concrete, and the like surfaces by means of dowels (Fig. 28). Clips are to be secured with dowel nails driven in by means of a pyrotechnical arbour charged with group "B" cart-

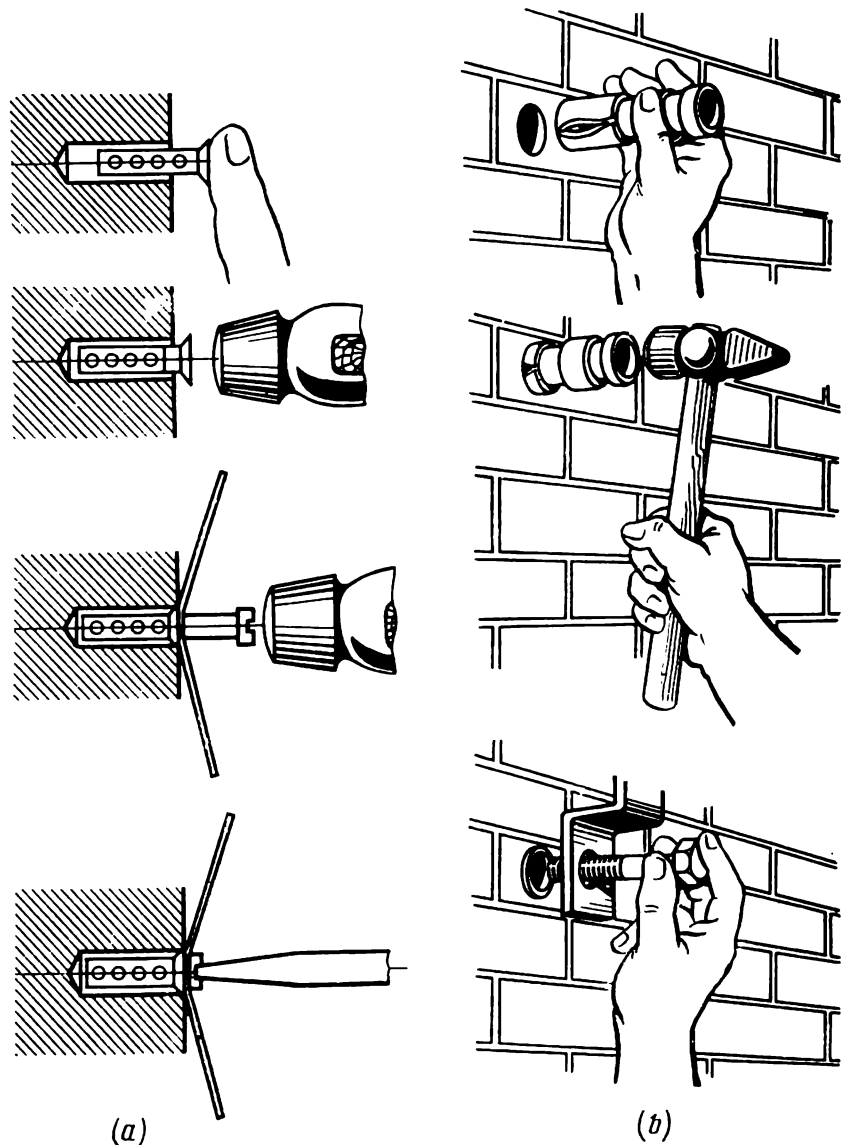


Fig. 50. Sequence stages of expansion dowel setting and fixing

a—crimped-filler dowels; b—expansion-nut dowel

ridges used for builders' guns. The carriage cap is fired at a blow on the arbour rod end with a hammer. Heavy clips and supporting structures for conduits are secured with expansion dowels (see Fig. 50a, b for the procedure of their fitting).

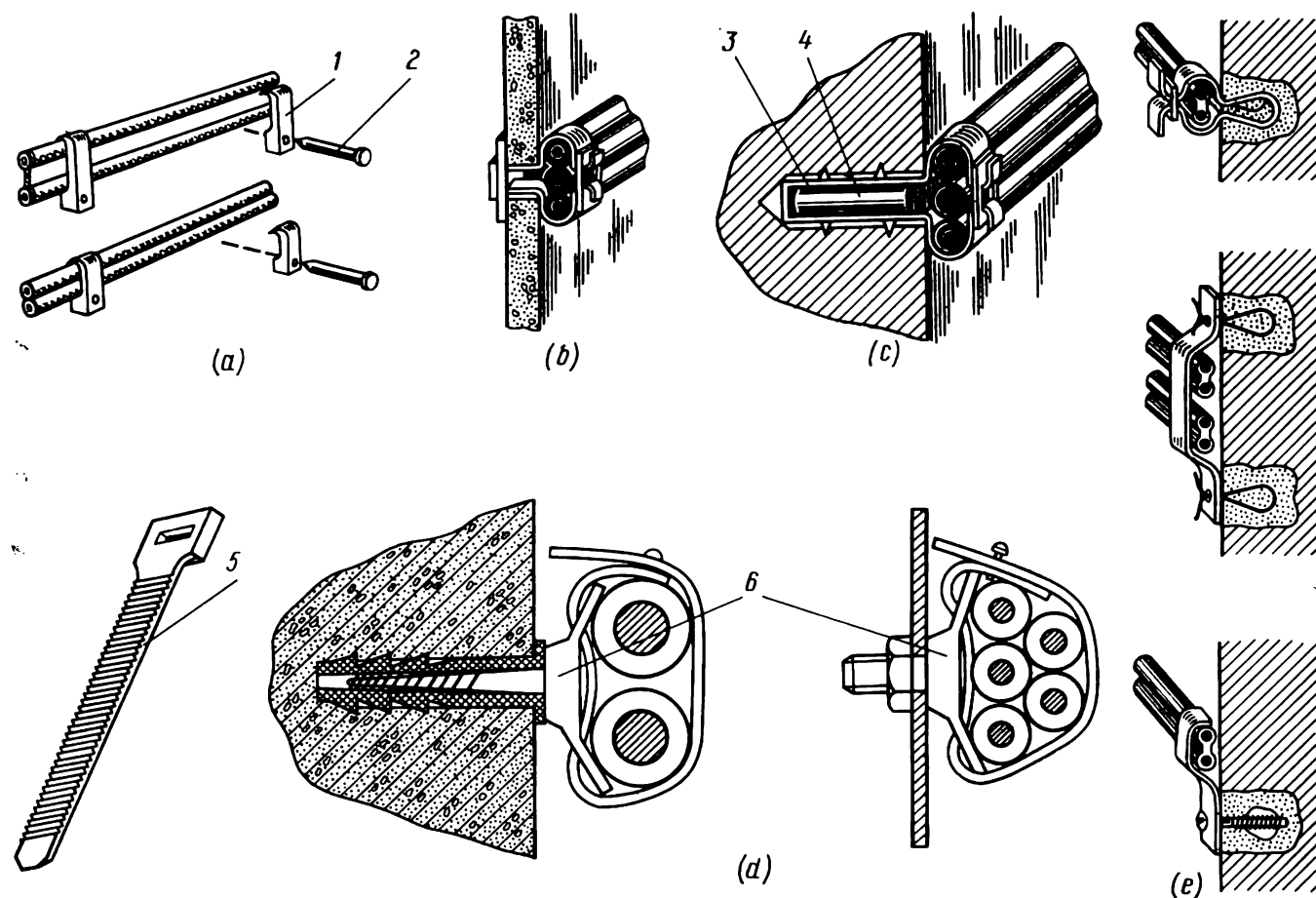


Fig. 51. Methods of wire attachment to building components

a—by elastic plastic clips; b—by clasp-terminated strip; c—by clasp-terminated strip with tenons and bar; d—by toothed retaining plastic strip and special fastener; e—finished joint; 1—plastic clip; 2—dowel nail; 3—steel strip with tenons; 4—metal bar; 5—toothed retaining strip; 6—special fasteners

The ТПРФ and АТПРФ wires can be also fixed by one of the methods illustrated by Fig. 51.

The ТПРФ and АТПРФ wires are to be bent by means of the КТ-1 pliers with changeable punches or by the КТ-2 pliers that are of a more advanced design and have a multipurpose rotating punch.

The bending radius of tubular metal-sheathed wires shall not be smaller than six-fold outer diameter of the wire sheath. In bending the pliers are indented into the sheath. Indented points shall be spaced at a minimum distance, but not overlap.

The punches shall correspond to the cross-sectional area of wires. While indenting, the sheath shall not be cut, otherwise the underneath insulation may be damaged.

Where ТПФ and АТПФ wires cross other wirings or pipelines, they shall be laid in open plastered channels or in a steel conduit running under the wiring or pipeline being crossed.

Where the ТПФ and АТПФ wires are to pass through plastered wooden, brick, or concrete walls, they are to be laid in insulating or plastic pipes and terminated with porcelain or plastic bushes.

Wires routed through intermediate floors are to be drawn into pipes to prevent damage to them.

The ТПФ wire is to be made off at the end by making a circular and a longitudinal cuts on its sheath. Insulating paper shall never be cut with a knife. It shall be torn by hands to prevent damage to conductor insulation.

The conductors of tubular metal-sheathed wires are to be joined together and spliced in splice or jointing sleeves (Y419, Y420, Y194, and the like) by welding, soldering, indentation, or by means of clamps.

Tubular metal-sheathed wires are to be entered into splice sleeves, devices, and appliances together with the sheath.

In humid, extra humid, fire hazard, and chemically active atmospheres use is made of БРГ, АБРГ, НРГ, АНРГ and the like rubber covered cables for lighting wiring systems. These cables are installed using the same procedures as for the ТПФ and АТПФ wires.

Rubber covered cables shall be installed at a temperature not lower than -15°C . In open wiring, the БРГ and АБРГ cables shall be protected against sun rays that may rapidly deteriorate the insulating properties of rubber.

Cables can be bent manually. The bending radius shall be at least a ten-fold outer diameter of the cable sheath.

Cable jointing and splicing are made in jointing and splice sleeves.

5.6.2. Installation of Open Wiring Systems on Insulating Supports

Insulating supports afford a constructionally simple method of wiring, though rarely employed due to their short service life and limited use of industrialized installation methods.

For open wiring mounted on insulating supports, use is made of ПП, АПП, ПБ, АПБ, ППБ, АППБ, and the like insulated wires installed on insulators reinforced by hooks, pins, anchors, and half-anchors.

Insulators are fixed on hardware by one of the following methods: by wrapping the ragged end of a hook in a few layers of minium- or whites-treated hemp or jute; by grouting the insulator interior in cement, melted sulphur, or heated polythene, by fitting a polythene cap on the hook end.

For fixing the insulator on hardware by means of minium treated hemp, the hook (pin, anchor, or half-anchor) is to be clamped in vices and its ragged end is to be wrapped in several layers of minium (whites) impregnated hemp (jute) until the wound hemp diameter becomes 8 or 10 mm larger than the insulator inner diameter so as to ensure its tight fit on the hook. Then a tow or felt packing is to be placed on the insulator bottom to prevent damage to the insulator through the butt portion of the hook due to lengthwise thermal expansion. The insulator is

to be turned in with a certain force as far as it will go and then turned out half the revolution. A drawback of this method of attachment is that the insulator may come loose after a short time of operation as the jute dries out.

Fixing the insulator on hardware by grouting in cement, melted sulphur, or heated polythene is to be made as follows. A tow or felt packing is to be placed on the insulator bottom, and the insulator is to be fitted onto a hook clamped in vices, with the rough portion being in the centre of the insulator hole, whereupon grade 400 or 500 cement grout is poured in until the hole is full. The same method is suited when using melted sulphur or polythene instead of cement. It shall be borne in mind that hot sulphur or polythene may make the insulator crazy so that with time it may be partially or fully deteriorated.

The best material for grouting the insulator is heated polythene that most readily meets the requirements with regard to mechanical strength, chemical resistance, and time consumption.

A general disadvantage of fixing insulators on hardware by grouting in cement, sulphur, or polythene is the difficulty of faulty insulator removal from hardware for replacement with a new one.

Fitting insulators on hooks is one of the most labour-consuming jobs; to facilitate the procedure, use is made of various mechanisms, such as a type CHИ-2 insulator mounting machine illustrated by Fig. 52*a, b*.

The CHИ-2 machine functions to turn polythene caps and porcelain or glass insulators on hooks at a time. The operator places hooks in the seats of a rotary circular table 1 and fits polythene caps on them with a hammer. Then the operator sets the insulator on the hook closest to the carriage 4 mounting a turning-on unit 6 and 7, turns the table and positions it by means of the retainer 2 so that the hook mounting the insulator is accurately under the friction cone 7 of the turning-on unit. Then the operator switches on the 0.6-kW motor 5 and pushes the pedal 8 to move the carriage with the turning-on unit down. The friction cone grips the insulator, turns it onto the polythene cap and, pushing further the pedal, rotates the insulator and turns it onto the hook together with the cap. As soon as the safety clutch 6 turns, the operator releases the pedal 8, and the carriage moves up together with the turning-on device. The same procedure is then repeated with the next insulator.

The CHИ-2 machine capacity is 150 to 160 insulator sets per hour.

Reinforced insulators are fixed to the building components on the marked-out route using one of the methods illustrated by Fig. 53*a* through *d*.

For fixing hooks or anchors with insulators to wooden components, it will be required to drill holes of a diameter 5 or 6 mm smaller than that of the hook or anchor threaded portion at the marked-off points. The hook and the anchor must be driven into the wooden component until the threaded portion fully enters the wood.

Pin-mounted insulators are supported by brackets.

In brick, concrete, and other building components, holes for insulator mounting hooks and anchors are made by means of electric drills furnished with extrahard steel-clad cutting tips. The hole for a hook must be long enough to receive the entire threaded portion of the hook and its diameter must be three times as large as that

of the hook. The hole for an anchor must be long enough to receive at least one third of the anchor threaded portion. Holes for brackets are made in the form of square seats with the square side length being twice the bracket leg width and the seat depth, one third the leg length, but not less than 50 mm.

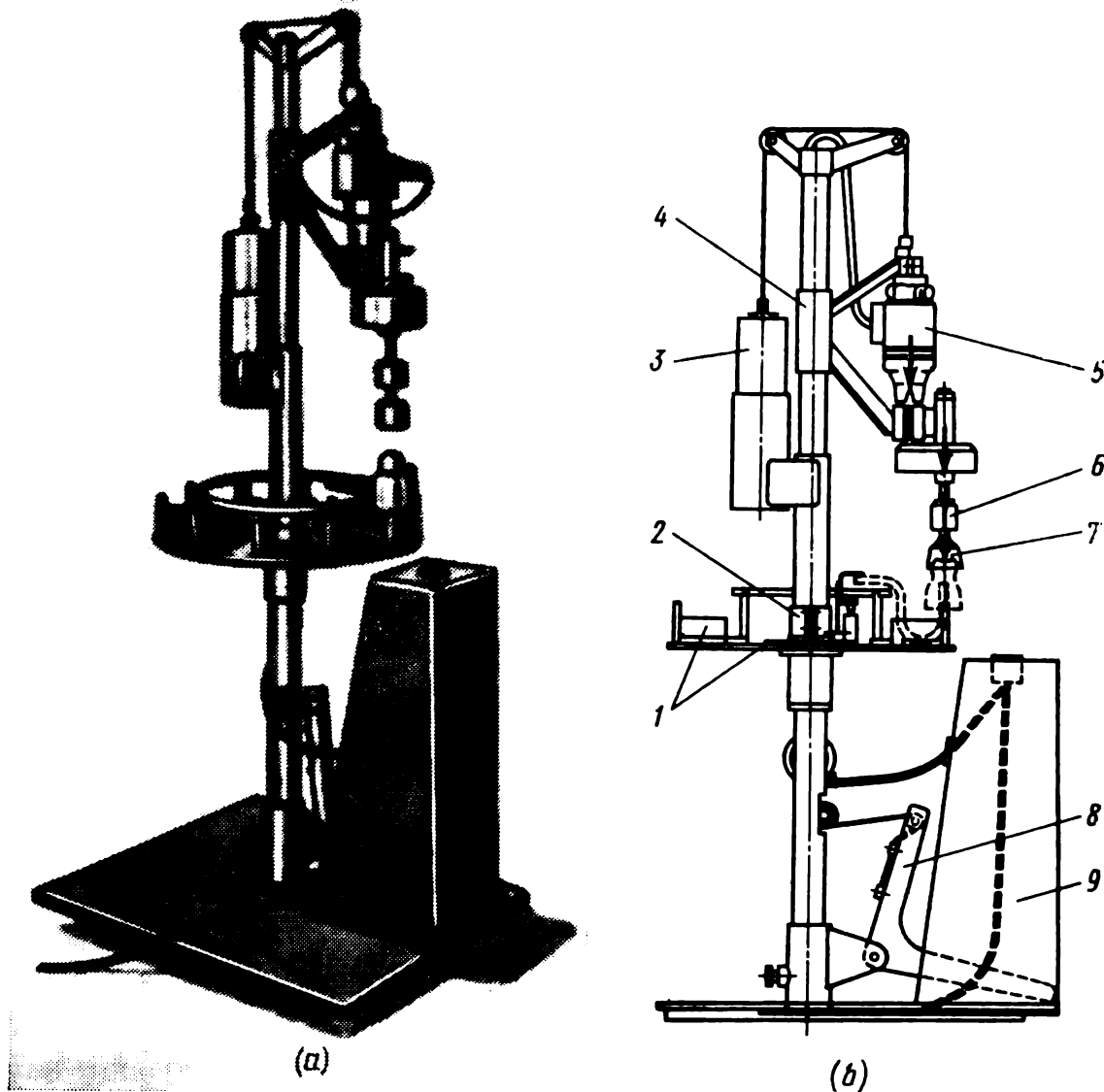


Fig. 52. Insulator mounting machine CHI-2

a—general view; b—general arrangement; 1—rotary circular table with twelve seats for hooks; 2—retainer; 3—counter-poise; 4—movable carriage; 5—electric motor; 6—safety clutch; 7—friction cone; 8—foot pedal; 9—machine control pillar

Prior to embedding, the threaded portions of anchors and hooks and the legs of brackets must be cleaned of dirt and oil; the holes to receive them must be cleaned of debris and moistened with water. Hooks, anchors, and brackets inserted in holes are to be grouted in cement mixed with sand in a proportion 1 : 3.

Wiring is started with laying out the preassembled wiring components along the route so that branches running to lighting fixtures, switches, and sockets are placed on insulators. This done, the wires are thrown on insulators, secured at the starting end of the wiring, tensioned manually or by means of a pulley block, and fixed to the insulator heads and grooves with zinc-plated wire, dia 0.8 to 1 mm. Before doing this, the wiring conductors are to be wrapped in two or three layers

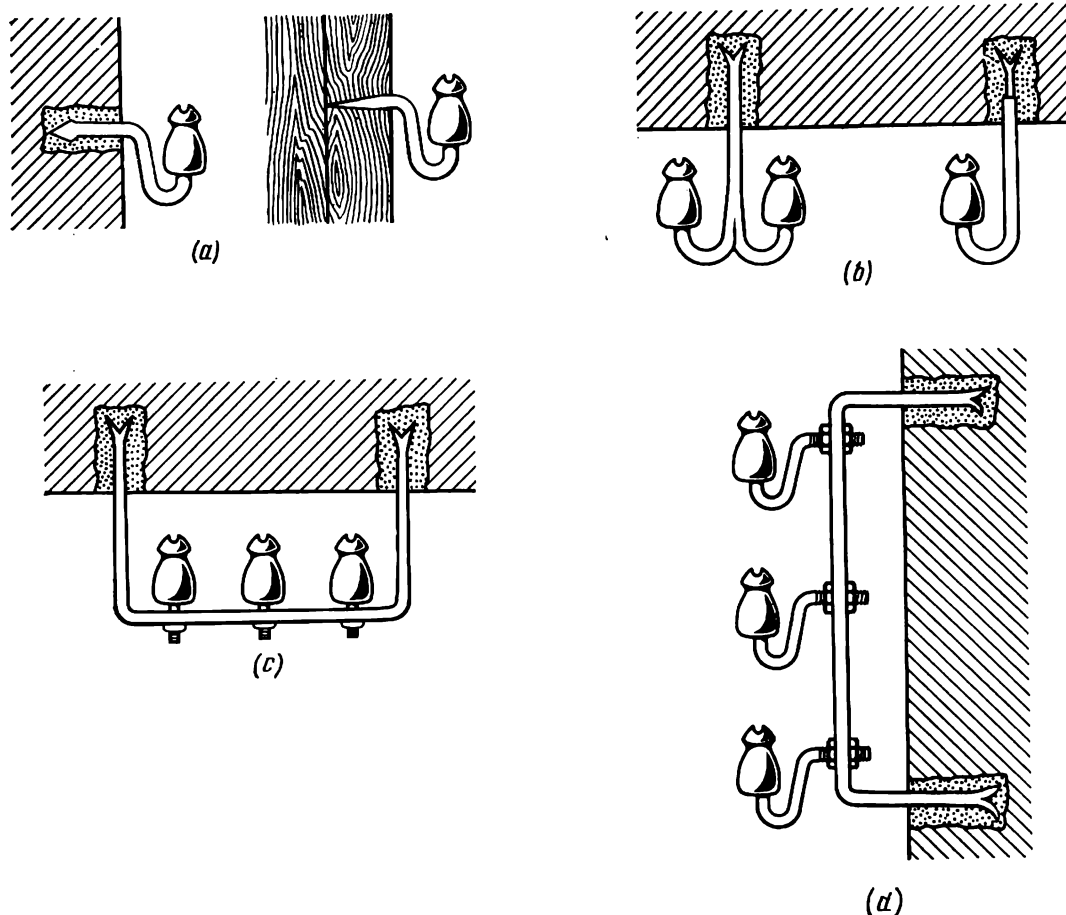


Fig. 53. Methods of insulator attachment to building components

a—hook mounting on concrete or wooden wall; *b*—anchor and semi-anchor mounting; *c*—mounting by pins on horizontal bracket; *d*—mounting by hooks on vertical bracket

of insulating tape to protect their insulation against damage that may be caused by safety wire. Conductors are secured on the insulator heads or grooves on straight portions of the wiring (Fig. 54*a, b*). Where the wiring makes a turn or changes its direction, the conductors are secured in grooves or by means of a bracing loop only (Fig. 54*c, d, e*).

At crossings, one of the crossing wires is placed in an insulating tube.

If prefabricated wiring systems are not available, then conductors are stretched on insulators, points of splicing and attachment are marked on them, whereupon the conductors are dropped, spliced to make the required taps, wrapped in two or three layers of insulating tape where they are attached to insulators, then raised again, stretched and secured in position as has been already described.

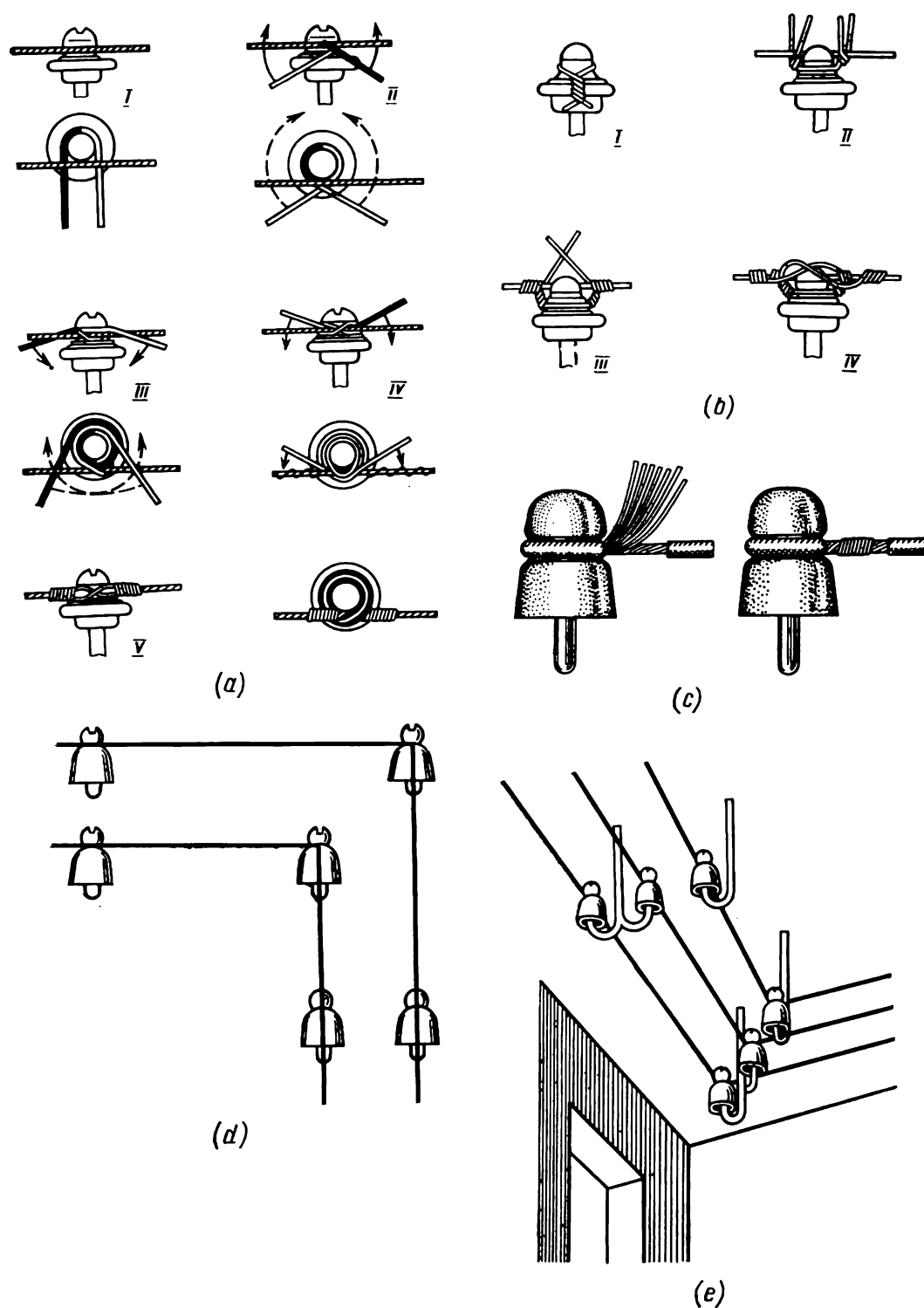


Fig. 54. Attachment of wires to insulators in open wiring
 a—in insulator groove; b—on insulator head; c—bracing loop; d—routing wires over a wall; e—routing wires over a ceiling

5.6.3. Open Wiring in Pipes

Open wiring in conduits may be sealed or nonsealed. Wire pipes are sealed at pipe-to-pipe and pipe-to-box joints by wrapping the threaded portions in hemp fibre impregnated with minium or whites. Sealed pipes are used in explosion-hazard, extra humid, or chemically active atmospheres to protect insulating and conducting materials against mechanical damage and corrosion. Sealed pipes must sustain test pressures specified for particular locations and atmospheres.

Thin-walled steel (electrically welded) pipes are employed for open wiring in dry, humid, hot, dusty, and fire-hazard locations. Vinyl pipes are used in moist

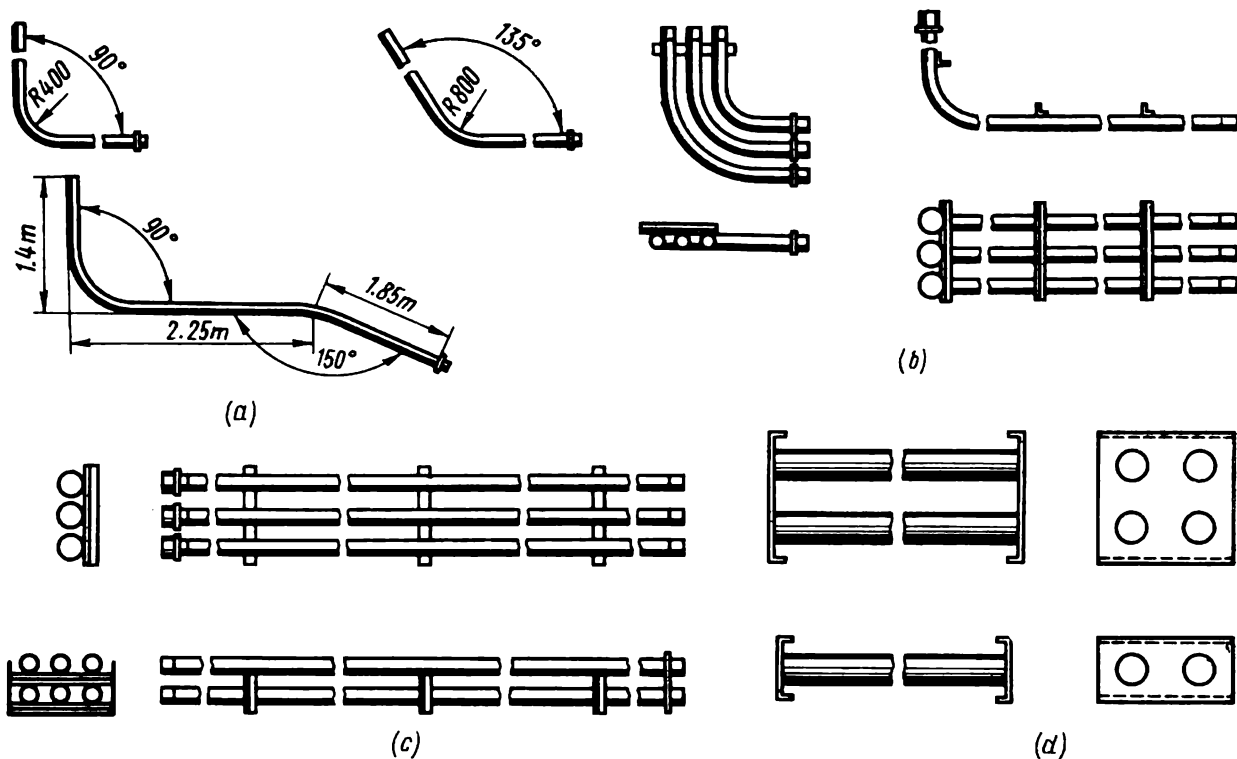


Fig. 55. Prefabricated conduits

a—pipes bent through standard angles; *b*—stacks of bent pipes; *c*—straight-pipe stacks and conduits; *d*—conduits with common flanges

and extra moist atmospheres. Open sealed wiring systems are usually installed in steel water and gas pipes. Pipes are selected and methods of their routing determined according to the project which depends on the purpose of wiring, category of location, operating conditions, and special requirements to the wiring system.

When an industrialized method is used, pipes, pipe stacks and conduits (Fig. 55*a* through *d*) are preassembled at a factory or a preassembly division against delivery lists. Preassembly procedures consist in cleaning the pipes, bending them through the desired angle, finishing the pipe ends for joining with other pipes or boxes by means of threaded sleeves, by welding, or by any other method, painting the pipes and assembling them in stacks and conduits.

Nonsealed exposed electrically welded pipes are joined together by means of a threaded jointing sleeve (Fig. 56a), a sleeve and a wedge (Fig. 56b), by soldering in a sleeve (Fig. 56c), or by a clip and screws (Fig. 56d). Vinyl pipes in sealed pipelines are joined together in sleeves set on adhesives and shrunk hot or welded.

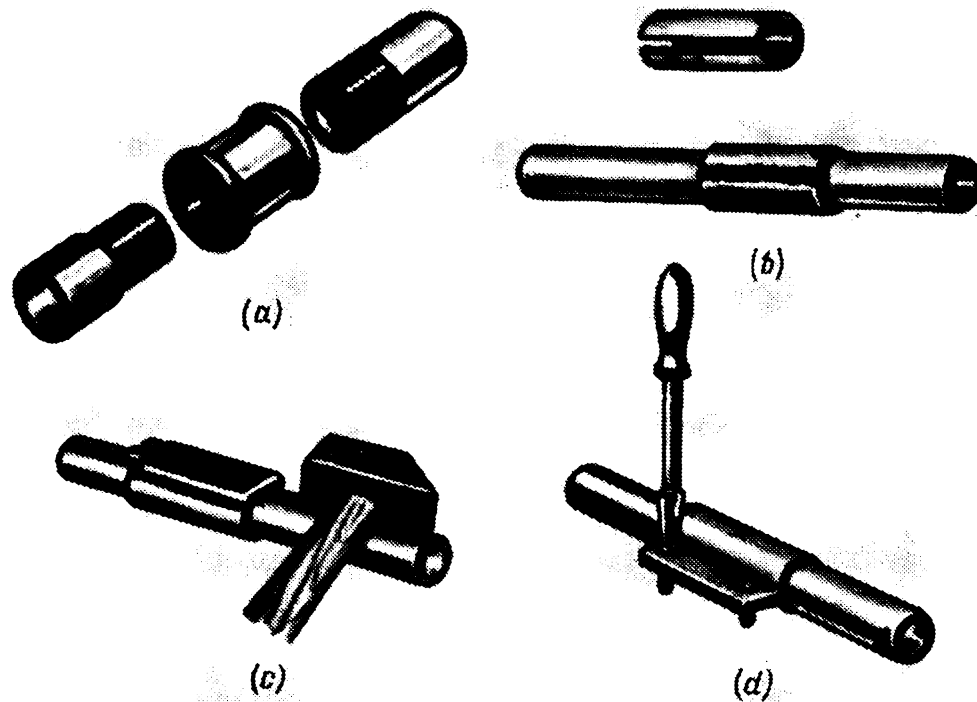


Fig. 56. Methods of connection of exposed thin-walled steel pipes

a—with threaded sleeve; b—with sleeve and wedge; c—by soldering in sleeve; d—with clip and screws

In nonsealed pipelines they are joined by sleeves without adhesives and welding.

To facilitate jointing the pipes and driving them into draw-in and branch boxes, it is good practice to keep to spacings between the centre lines of the pipes specified by Table 19.

Table 19

Minimum Spacings between the Centre Lines of Single and Stacked Steel and Vinyl Pipes

Effective passage of water and gas pipes		Outer diameter of electrically welded pipes, mm	Minimum spacing, mm, between centre lines of pipes		Outer diameter of vinyl pipes, mm	Minimum spacing between centre lines of stacked pipes, mm
mm	inch		single	stacked		
15	1/2	20	50	60	20	32
20	3/4	26	65	80	25	40
25	1	32	65	80	32	50
32	1 1/4	39	80	100	40	60
40	1 1/2	47	80	100	50	70
50	2	59	105	120	63	80

Single pipes are secured to the surfaces of building components by clips and dowels (Fig. 57a) or by fasteners (Fig. 57b).

Special supporting structures are employed to secure a number of adjacent pipes (Fig. 57c, d, e, f). Fixation by welding (Fig. 57e) is admitted only when water and gas pipes of normal wall thickness are routed.

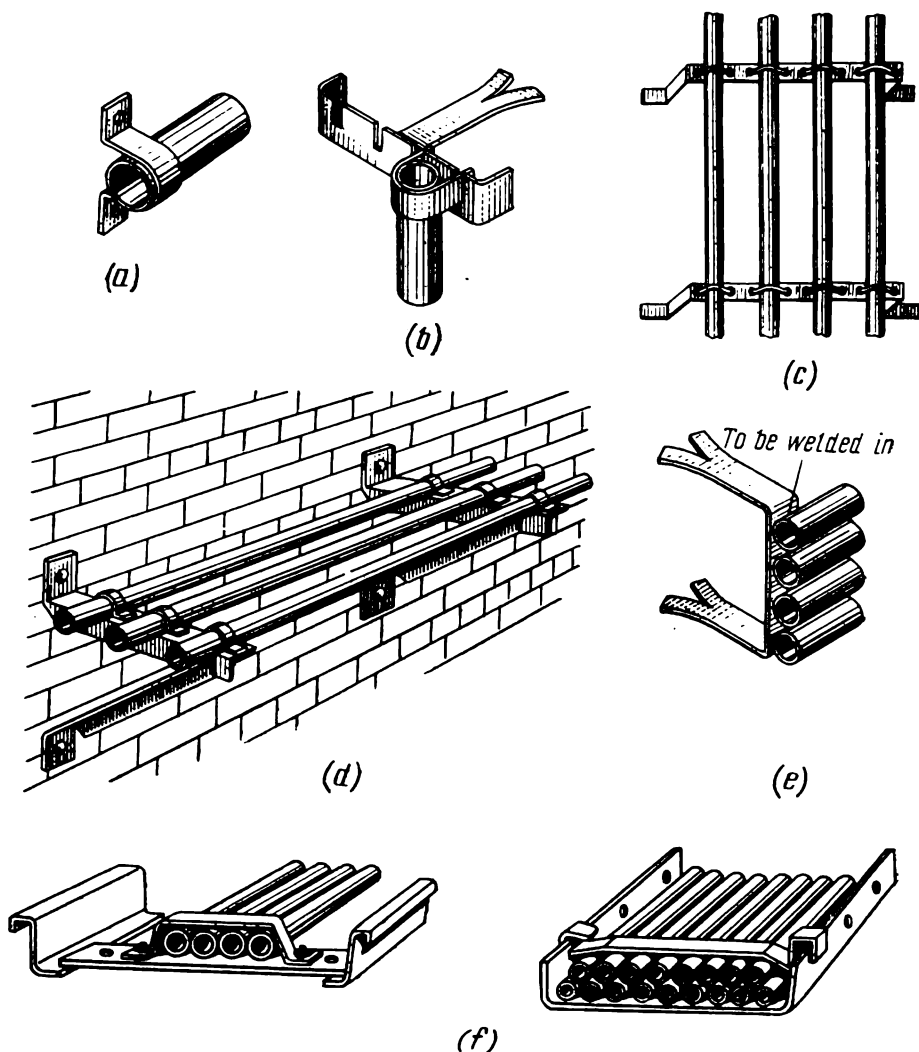


Fig. 57. Fixation of steel pipes to the surfaces of building components

a—single pipe, by clip with lugs; b—by fastener; c—several pipes, by extension dowel fixed clamp; d—on brackets; e—by welding pipes to embedded clamp; f—multiple pipes in troughs;

When steel pipes of the wiring system are used as earthing conductors, a reliable contact between pipes must be ensured and the electric circuit over the entire pipeline must not be interrupted.

The attachment points on open steel pipes shall be spaced apart as follows: 2.3 to 2.5 m for dia 26 mm pipes; 2.8 to 3 m for dia 32 to 40 mm pipes; 3.5 to 4 m for dia 50 mm and larger pipes.

Wiring conductors laid in pipes are interconnected and spliced in junction, branch, and draw-in boxes.

The number of boxes to be installed on the pipeline depends on the length and character of the route. The maximum length of a pipeline between two adjacent boxes depends on the number of bent portions of pipes in a section and must not be greater than 50 m on a section with one bend, 40 m on a section with two bends, 20 m on a section with three bends and 10 m on a section with four bends.

Pipes are installed with a downgrade towards the draw-in and branch boxes at least 3 mm per meter of the pipeline. When this is the case, moisture due to surrounding air vapours condensed in pipes does not accumulate in them.

Branch and draw-in boxes for conduit wiring systems installed in moist and extra moist atmospheres must be furnished with special moisture collectors provided with a special fitting to drain moisture accumulated in them. Plugs closing the fittings or tee-joints are to be set on minium-impregnated tow.

Steel pipes can be joined together and to boxes by various methods (Fig. 58a through f). In dry and nondusty atmospheres free from chemically active gases detrimental to insulation, steel pipes may be joined together by means of collars without seals.

Where pipes are used as earthing conductors, provision shall be made to afford a reliable electric contact at the point of their connection. To this end, a flexible or rigid metal connecting wire is to be welded to them (Fig. 58f).

Where a steel conduit wiring is to pass through expansion or setting joints of a building, use is made of fittings (Fig. 27c) joined together in a metal sleeve and installed on both sides of the joint at a distance of 300 mm from the joint.

The pipe is welded to a box or a sleeve is screwed on the pipe and on the pipe union welded to the box. To ensure a reliable contact between the pipe and the

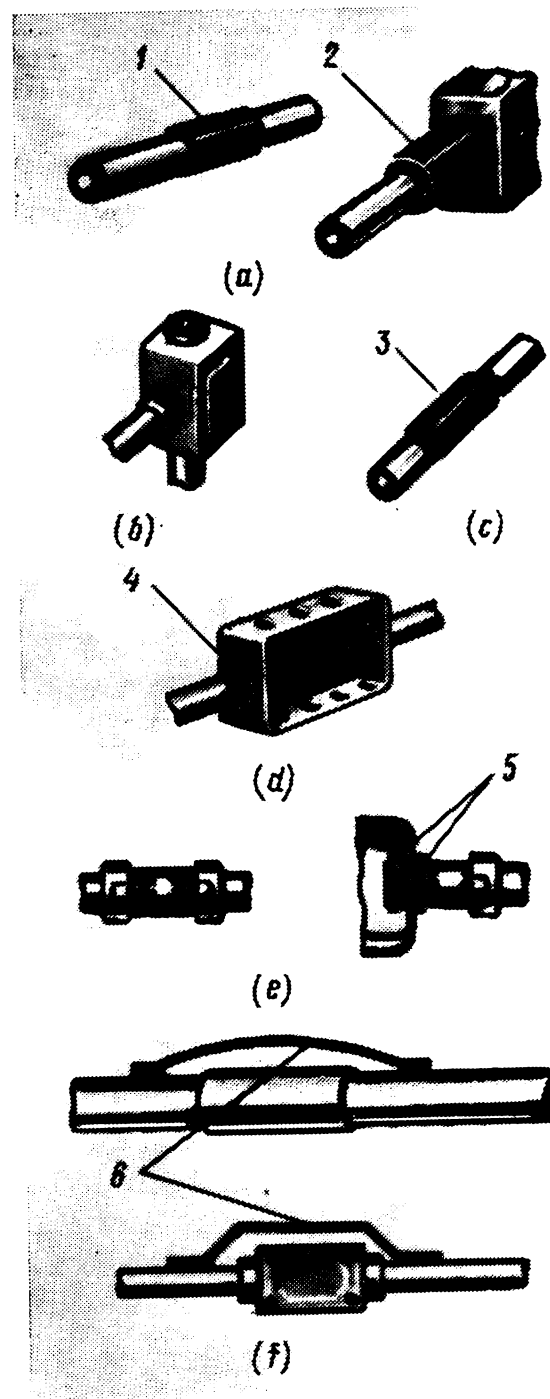


Fig. 58. Methods of connection of steel pipes to one another and to boxes

a—by welding in sleeve and in box pipe union; b—by bringing the pipe directly into the box; c—by threaded sleeve; d—by sprocket nuts; e—by sleeve and locking nuts; f—by welding, with connecting wire by-passing the sleeve and box; 1—sleeve; 2—box pipe union; 3—threaded sleeve; 4—sprocket nut; 5—locking nuts; 6—connecting wires completing the circuit by-passing the sleeves and boxes

Table 20

**Selection of Steel Pipes to Receive Single-Conductor Wires,
ПР, АПР, ПРТО, АПРТО, ПБ, ПРБ, and АПРБ**

Pipes		Maximum permissible number of wires per pipe at conductor sectional area, mm ²		
Water and gas effective passage, mm	Electrically welded, outer diameter, mm	2	3	4
20 25 40	26 32 47	4-6 10-16 25-35	4-6 10-16 25-35	4-6 10 25
50 70 80	59 — —	50 70 95-120	50 70 95	35 50 70

box, the pipe ends are provided with sprocket nuts (Fig. 58*d*) so that they are tightly fitted to the box surface cleaned off to metal lustre. Connections to devices are usually made by means of locking nuts screwed onto the pipe end introduced into the device being connected.

For conduit wiring use is made of wires ПРТО, АПРТО, ПБ, АПБ, ПР, АПР, and cables БРГ, АБРГ, НРГ, АНРГ.

Types, cross-sectional areas, and number of wires and cables laid in pipes, and also inner sizes of pipes are determined by the project. For the selection of sizes of steel pipes meant to accommodate single-conductor wires refer to Table 20.

Wires are drawn into steel pipes either manually or by special pullers. Wires laid in vertical pipings (standpipes) must be reliably fixed in position by means of cleats

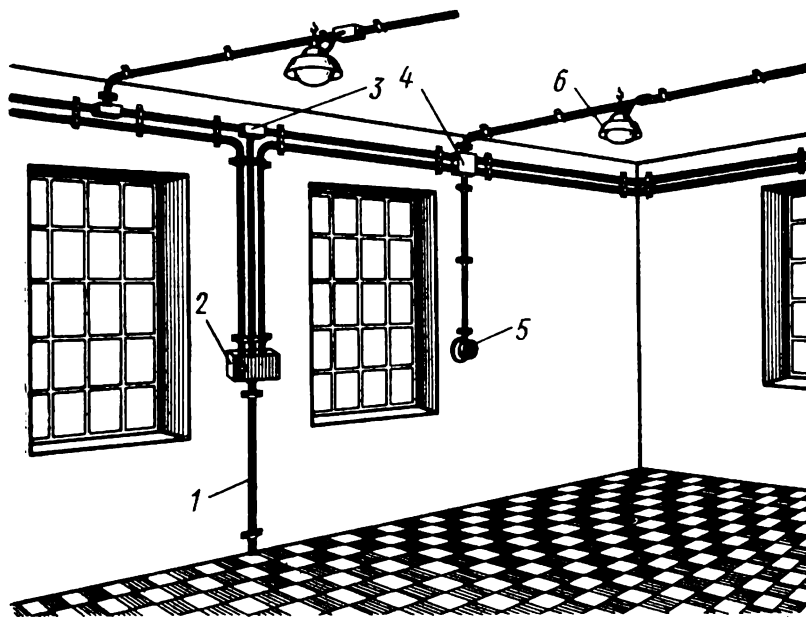


Fig. 59. General view of lighting system wired in thin-walled pipes

1—power supply to distribution board; 2—distribution board; 3—draw-in box; 4—splice box for branching wires to on/off switch and to lighting fixture; 5—on/off switch; 6—lighting fixture

and clamps installed at the ends of pipes or in draw-in boxes. Fixing points must be spaced apart at least 30 m for wires of up to 50 mm² area and 20 m for those up to 70 mm² and larger areas (see Fig. 59).

5.7. Installation of Catenary Wiring Systems

A catenary wiring system is made of special cables and of shielded and non-shielded insulated wires and cables supported by catenary cables that are attached to building components.

Catenary wiring systems are special open wiring systems used to feed lighting and power consumers of industrial plants, where there are no overhead travelling cranes; they are also used for external lighting systems for illuminating streets, factory territories and stores.

Catenary wiring systems offer the following basic advantages:

- (a) full industrialization of work by using preassembled wiring components delivered from a preassembly division;
- (b) simple mechanical design and small number of fastenings required;
- (c) provision for mounting, disassembling, and carrying the wiring components to another place within short time and without interrupting the production process;
- (d) low cost of labour and installation jobs;
- (e) convenience and safety in service.

Catenary wiring systems are usually installed in two stages.

The first stage includes all the preparatory and preassembly jobs, such as:

- (a) installation and surface finishing of embedded parts and supporting structures;
- (b) preliminary treatment of the catenary wire or cable (straightening, cleaning, cutting to desired lengths, terminating the catenary end in a loop, a thimble* or any other fitting for its connection to the supporting structure); treatment of wires and cables, such as trueing, marking off, cutting to desired lengths, skinning conductor leads, fitting and securing splicing clips, connecting (soldering, welding) the conductors, terminating the conductors, connecting the cables and wires to devices and instruments.

All the preliminary and preassembly jobs are carried out either on site of installation or at a preassembly division (if industrialized installation method is used).

Installation of a catenary wiring system is started from mounting and sealing embedded parts and supporting structures. These jobs are carried out while the building is still under construction. If such a wiring system is to be installed in a building already erected, these jobs are to be carried out by electricians who must use motor-driven mechanisms with hard-alloy cutting tools for drilling holes and wells in building components.

Catenary wires and cables carrying the wiring system are to be secured by means of end fastenings rated to take a strain of 500 and 1600 kgf (Fig. 60*a* through *f*).

The following accessories are used to support, suspend, and guy the catenary wiring elements: steel cable (rope), dia 1.95 to 6.5 mm; zinc-plated steel wire, dia 2.5 to 6 mm; hot-rolled round wire, dia 5 to 8 mm; bare zinc-plated steel wire,

* A thimble is a long grooved steel holder inserted into the loop at the end of a catenary to prevent the latter from attrition at the point where it is connected to a supporting structure.

dia 6.8 and 7.5 mm, stranded of standard steel or copper-plated steel wires; wire rope used as a catenary and a neutral wire at the same time.

Preassembly jobs include installation of the catenary wire or cable, attachment of hangers, splicing clips for aluminium and copper wires, and boxes for type

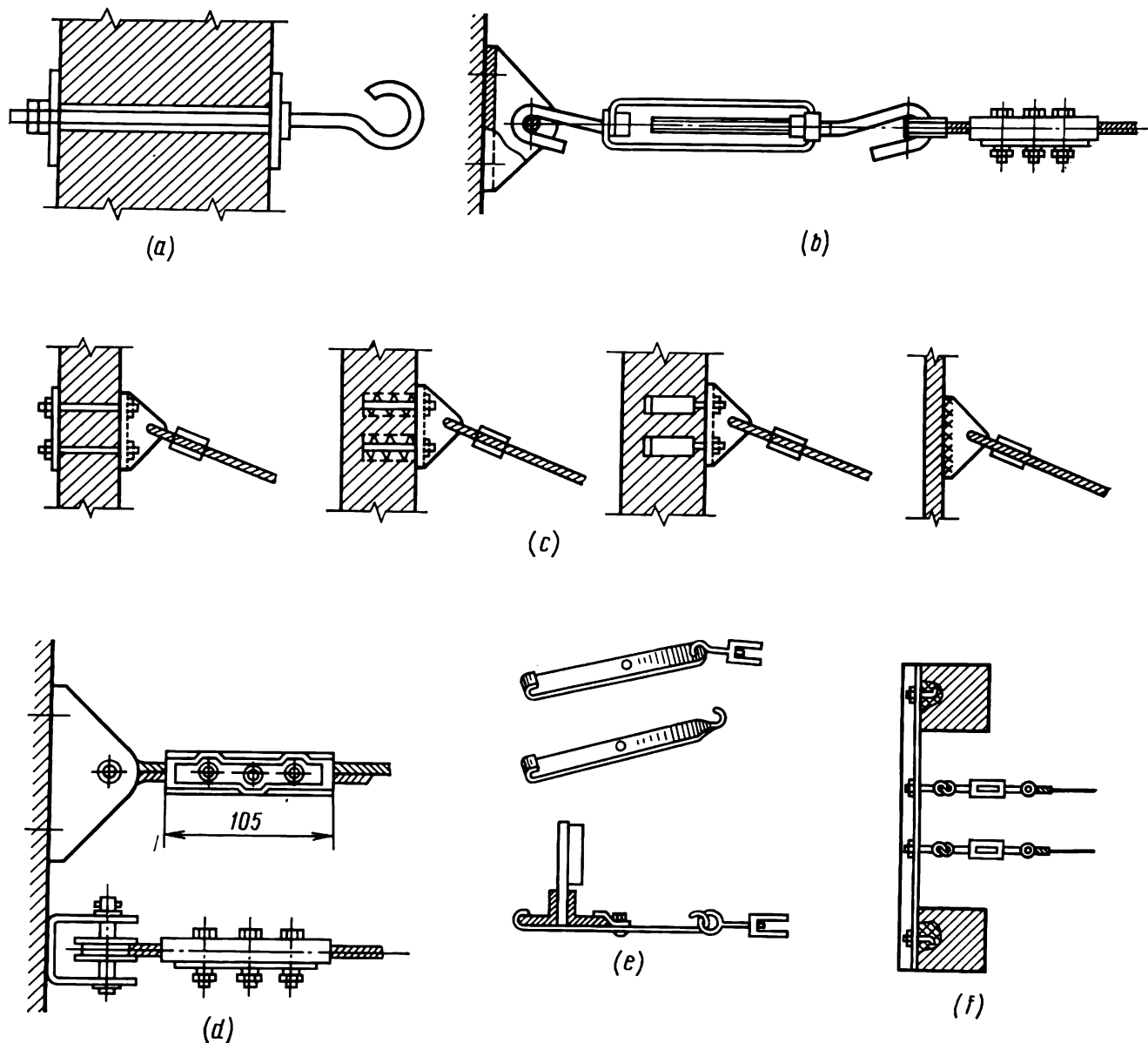


Fig. 60. End fastening accessories for catenary wiring systems and methods of their installation
a—strain bolt and hook assembly; *b*—catenary strain anchor; *c*—anchors for end fixation of wire strings secured by studs, pins, dowels, and by electric welding; *d*—catenary anchors for end fixation of prefabricated steel catenary wires or cables; *e*—accessory for fastening the catenary and the wire string to metal trusses made of shaped steel and tee-section beams; *f*—arrangement for fastening parallel catenaries

AHPT wires, jointing and dropping of wiring elements for their connection to supply mains.

Branches from main lines made of three- and four-conductor wires, type APT, are made by means of splice boxes (Fig. 61*a*) that are available of three types, viz.,

type 0.2 for lighting and power circuits with main-line and branch-circuit conductor sectional area of 4 to 10 mm² and 1 to 2.5 mm², respectively; type C2 for lighting and power circuits with main-line and branch-circuit conductor sectional area of 4 to 10 mm²; type C3 for power circuits with main-line and branch-circuit conductor sectional area of 16 to 35 mm² and 4 to 10 mm², respectively.

For making taps from main-line aluminium and copper conductors use is made of cross and tee clips (Fig. 61b). For splicing conductors of 6, 10, and 16 mm²

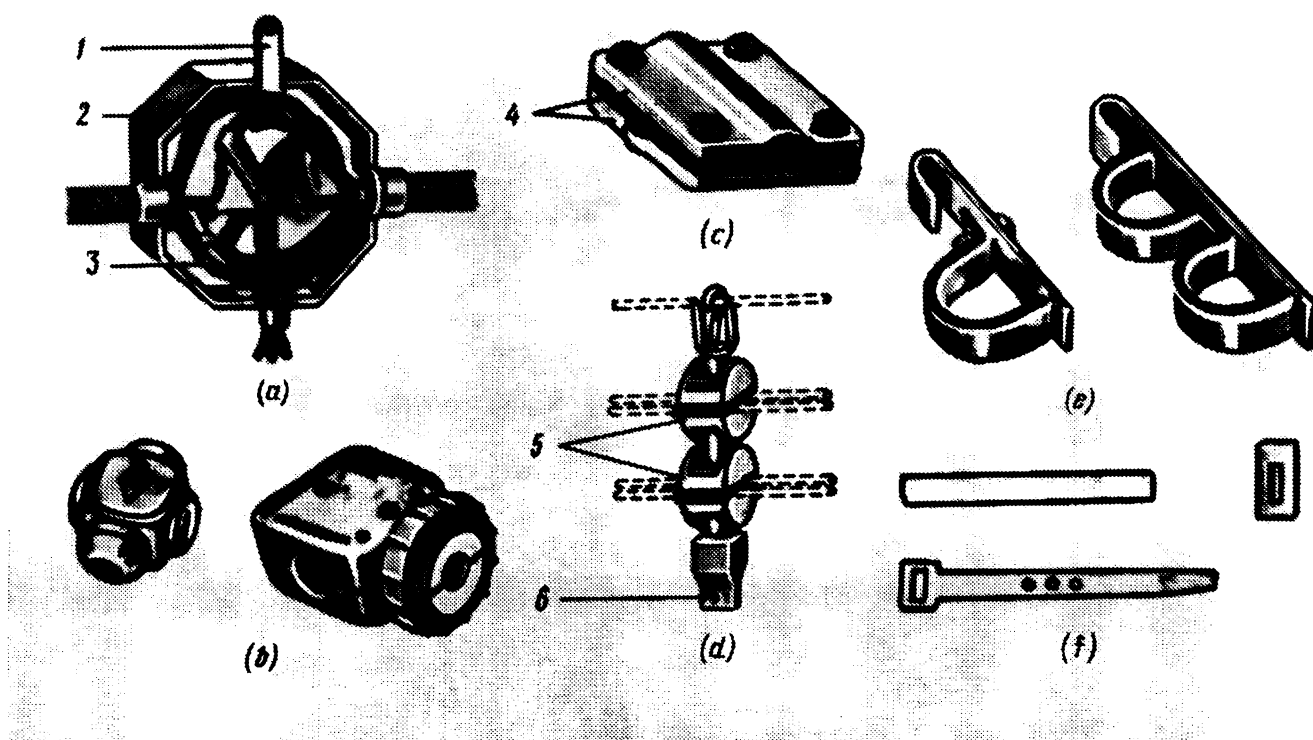


Fig. 61. Accessories for fastening catenary wiring systems

a—branch box to make branches from main line; *b*—cross and tee clips; *c*—die-plate clip; *d*—hanger with plastic cleats; *e*—steel hangers; *f*—strip with clasp and clasp-terminated strip; *1*—branch box fastening strip; *2*—box body; *3*—terminal; *4*—die-plates; *5*—hanger cleats; *6*—lighting fixture eye

area, tapped off main-line wires of 35 and 50 mm² area, die-plate clips (Fig. 61c) are used.

A plastic hanger Y930 through Y934 (Fig. 61d) is used for holding four insulated conductors up to 6 mm² area and lighting fixtures on a dia 4 to 7 mm catenary wire. A steel hanger Y954 through Y956 (Fig. 61e) is employed to hold a cable on a catenary cable of up to 10 mm.

A steel strip complete with a clasp or a clasp-terminated strip (Fig. 61f) serves for binding cables and wires.

The second stage includes the following operations: preassembled sections and units of catenary wiring systems are assembled into a common line and suspended

from strain facilities and supporting structures that have been installed during the first stage of installation.

A preassembled catenary wiring system delivered to the installation site is to be unreeled and set straight. During this operation the wiring system is to be checked for condition and for missing items. If the wiring system is delivered by separate sections and units, these components are to be assembled into catenary lines and the complete wiring system is to be suspended on site. Figure 62 shows schematically how to assemble and secure catenary wiring system elements.

For assembling a catenary wiring system and suspending its elements, one end of the catenary wire or cable (right-hand, on Fig. 62) is to be terminated with

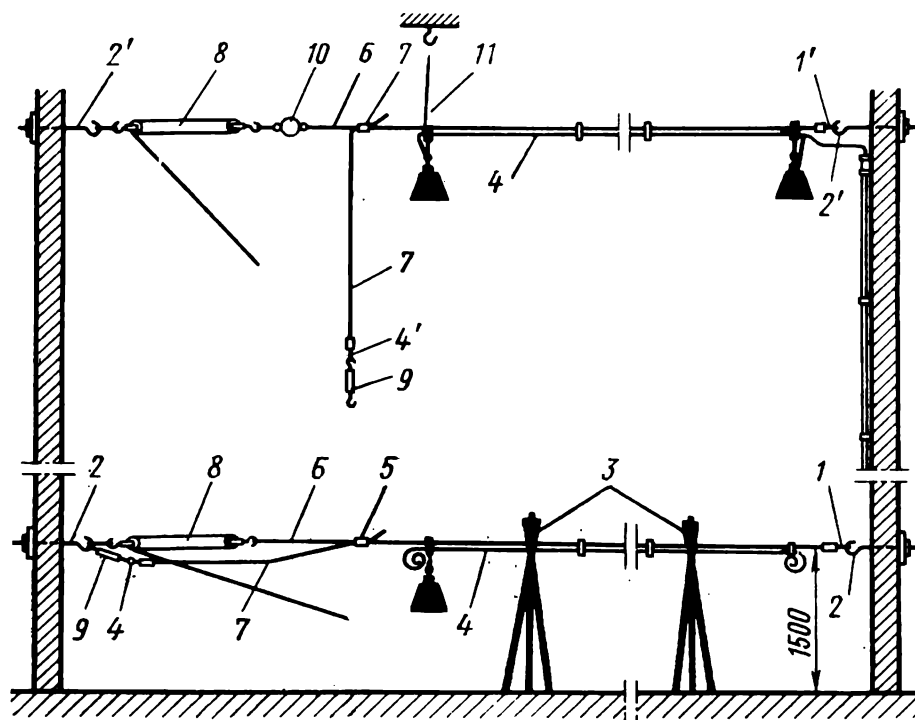


Fig. 62. Assembling and securing a catenary wiring system on site of installation

1 and 1'—catenary and loops; 2 and 2'—temporary and permanent anchors; 3—implementary supports; 4—catenary wiring line; 5—wedge clamp; 6—auxiliary catenary wire length; 7—catenary loose end; 8—pulley block; 9—slack adjuster; 10—dynamometer; 11—vertical wire hangers

a loop 1 that is to be thrown on a temporary right-hand anchor hook 2 mounted at a height of 1.5 m. The other temporary anchor hook 2 mounted on the opposite wall of the room is to be attached to the loop of one end of a pulley block 8, the loose end of the latter being secured to the wedge clamp 5 that grips the catenary at a certain distance from its end loop. In the action, the loose end (left-hand, on Fig. 62) of the catenary carrying a slack adjuster 9 is set in a suspended position. The catenary suspended between temporary anchor hooks, together with all the wiring elements attached to it, is then tensioned by the pulley block till the desired sag is obtained. The catenary tension is checked against a dynamometer fitted between the pulley block and the wedge clamp.

In tensioning the ATPГ catenary wires, forces applied shall not exceed 100 kgf for catenary wires of 4 to 10 mm² area and 500 kgf for those of 16 to 35 mm² area.

Upon stretching the wiring system, the loose end of the catenary wire carrying the slack adjuster is to be attached to the left-hand anchor hook 2, the pulley block 8 released and removed from the hook. This done, implementary supports 3 are to be mounted under the catenary wire or cable to hold the wiring system at a height convenient for operation.

For the finishing job, the bodies of lighting fixtures, with glass components (reflectors, globes, etc.) removed, are to be suspended from the catenary and fixed in position, the height of wiring between anchor joints adjusted by varying the length of hangers 11, and miscellaneous operations carried out to complete the installation.

The assembled wiring line is to be raised, connected to the anchor fastenings and slack adjuster, stretched by means of slack adjusters, the length of vertical wire hangers finally adjusted and the latter secured in position, bulbs inserted in place, reflectors and globes fitted in the lighting fixtures, and all the wiring components checked for correct positioning relative to one another.

As is specified by the Regulations for Electrical Installations, the elements of a catenary wiring system (catenary wire or cable, bodies of lighting fixtures, cable sheaths, etc.) must be earthed. To this end, the fixtures of the catenary wiring system and the catenary wire or cable are to be connected to earthing busbars by means of a steel cable, at least 5 mm in diameter, or a stranded copper wire of at least 2.5 mm² cross-sectional area.

When the catenary is also used as a neutral or earth conductor, the connecting wire or cable must have a cross-sectional area corresponding to that specified for a neutral or earth conductor.

For earthing, the desired length of a cable or flexible stranded copper conductor of the appropriate cross-sectional area is cut off to be used as a connecting conductor. A steel sleeve or strap is to be welded to one end of the connecting conductor and to the earthing busbar. The other, loose end of the connecting conductor is to be connected to the catenary wire or cable through a bolt clamp.

Metal supports and cables mounted on the catenary are to be earthed by reliably fixing them to the latter.

Catenary wiring systems using type ATPГ wires are to be earthed by connecting the skinned portion of the catenary cable or wire to the branch box that accommodates a special facility.

Where lighting systems have a solidly earthed neutral, the anchor arrangement of special boxes or the neutral conductor of standard boxes is also to be connected to the lighting fixture body and to its neutral wire. When this is the case, the wiring system and the catenary are earthed through the neutral conductor of the lighting network.

Metal bodies of lighting fixtures used in open catenary wiring systems are to be earthed through special insulated copper conductors having a cross-sectional area of minimum 1.5 mm². The earthing conductor leads are to be connected to the lighting fixture body through earthing screws; their connection to the neutral

conductor or to the catenary (if the latter is used as a neutral conductor) is to be made through soldered joints or mechanical clips.

In open catenary wiring systems made of shielded wires and cables the lighting fixtures are to be earthed through a special conductor provided in the cable or wire. When this is the case, the earthing conductor is to be connected to the lighting fixture body (inside or outside of it depending on the lighting fixture design) and not to the neutral wire in the branch box.

Upon the erection of catenary wiring system:

(a) insulation resistance of the catenary wiring conductors is to be measured with a 1,000-V megger, with all the fuse links and bulbs removed, but switches, plug sockets, and branch-circuit distribution boards connected; the insulation resistance must not be lower than 0.5 MΩ;

(b) the catenary wiring and its branch circuits are to be checked for correct phasing-out;

(c) conductor-to-catenary insulation is to be checked for condition and the catenary-branch box-earthing conductor circuit is to be tested for continuity.

The results of all the above checks being adequate, the catenary wiring system may be accepted for service.

5.8. Installation of Concealed Wiring Systems

Concealed wiring systems are those laid under plaster, in closed channels of building components, and in raceways embedded in prefabricated building components.

Concealed wiring systems may be replaceable and nonreplaceable. A replaceable wiring system is distinguished from a nonreplaceable one in that any faulty conductor of its line can be easily replaced by a new one. It also differs in the assembly procedure.

When a replaceable wiring system is installed, the first operation is to insert pipes (semi-hard rubber, plastic, etc.), with wires passed through them, into raceways, channels, or under plaster, and only after that are conductors drawn in by means of these wires through draw-in boxes.

When a nonreplaceable wiring system is erected, conductors are first drawn into pipes and only after that the latter are routed over shortest possible distances and bent in the desired direction as many times as required, whereupon they are embedded in building components by plastering or grouting in cement. Figure 63*a, b* illustrates how replaceable and nonreplaceable concealed wiring can be made.

Before installing a replaceable concealed wiring system, it will be necessary to place draw-in boxes and pipes with steel wires passing through them, whereupon the preassembled wiring sections are pulled through the pipes by means of these auxiliary wires. It is likewise allowable to draw the conductors into the pipes and then to fix the latter on the route. When this is the case, any of the conductors laid in the pipes can be easily replaced by a new one.

The conductors of a replaceable concealed wiring system are pulled into branch boxes in a conservative quantity so that they could be easily connected therein by compression or welding.

Concealed wiring is made upon finishing the plaster and float work, but before starting the painting work. Conductors are usually laid in half-hard rubber, bitumen-treated rubber, or plastic pipes.

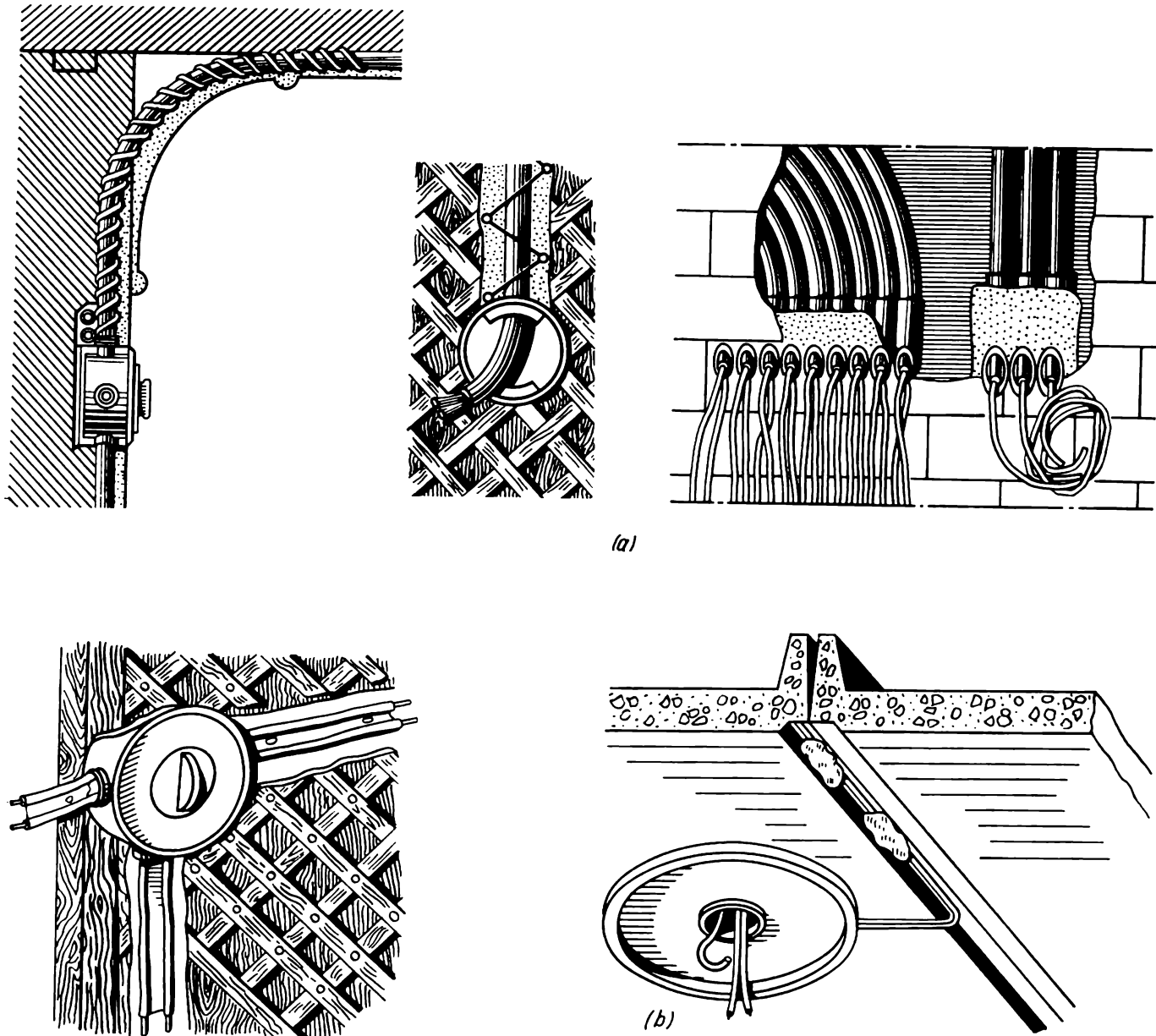


Fig. 63. Concealed wiring systems
a—replaceable; *b*—nonreplaceable

5.8.1. Concealed Wiring in Half-Hard Rubber Pipes

This wiring is made by one of the following two methods.

By the first method one or more conductors are drawn into a separate pipe, whereupon the pipes are laid into channels (blockouts) made in the walls and partitions in one layer only, and then plastering staff is applied to them.

By the second method, steel wire lengths, dia 1.2 to 1.5 mm, are drawn into the pipes and the latter are placed into channels. Conductors are pulled into the pipes by means of the steel wires after plastering work is finished and the walls are dried out.

To facilitate pulling of the conductors into the pipes, use is made of draw-in boxes mounted when the adjacent branch boxes are spaced more than 10 m apart. Conductors may also be drawn into pipes before placing the latter in channels to facilitate this work.

When conductors are laid in half-hard rubber pipes over wooden or the like easily burning surfaces, a coat of alabaster mortar, at least 5 mm thick, is to be applied under the pipes, or asbestos boards, at least 3 mm thick, are to be placed underneath. The alabaster coat or the asbestos boards are to protrude at least 15 or 20 mm on either side from under the pipes. The pipes are secured to a wall by means of zinc-plated wire tied to nails that are driven into the wall in a staggered manner. A plaster coat is applied over the pipes.

Pipes laid in channels or grooves made in brick or concrete walls are to be fixed in position by alabaster mortar.

Half-hard rubber pipes are to be bent manually, the bending radius being equal to a six- to ten-fold pipe outer diameter. The bent portions of the pipes are to be covered with insulating tape to make them harder, and zinc-plated wire, dia 1 to 1.5 mm, is to be coiled overall to facilitate the pulling of conductors into the pipe.

To ensure hermetic sealing, the pipes are to be trimmed at the ends and coated with hot bituminous compound МБ over a distance of 30 to 40 mm. This done, the pipes are to be inserted into a sleeve made of a pipe of a greater diameter, 100 to 120 mm long. The sleeve is to be coated at the ends with thick bituminous compound, the joint is to be covered with two layers of insulating or resin tape, and bituminous compound is to be applied on the insulation. The exposed ends of the rubber pipes are to be terminated with bushes or boxes.

For connecting the wire leads to a switch or to a socket outlet installed in a concealed wiring system, the pipe ends together with conductor leads are to be brought into the switch or socket shroud.

5.8.2. Concealed Wiring in Bitumen-Treated Rubber Pipes

Concealed wiring in bitumen-treated rubber pipes is to be laid over incombustible building components in normal and fire-hazard locations.

These pipes shall never be used in atmospheres containing chemically active agents, such as oils of all kinds, etc., at temperatures permanently exceeding 40°C, and near sources of radiating heat, nor shall they be employed in explosion-hazard locations.

Wires laid in bitumen-treated rubber pipes shall be covered with insulation rated at a working voltage not lower than 500 V, such as types ПП-500, АПП, ППТО, АППТО wires.

To ensure the desired mechanical strength, use shall be made of insulated copper wires having a conductor cross-sectional area of at least 1.5 mm^2 or aluminium wires of at least 4 mm^2 area.

Concealed wiring in bitumen-treated rubber pipes is made in the same sequence as in half-hard rubber pipes.

Figure 64a illustrates how to join the pipes in a sleeve made of a bitumen-treated rubber pipe length.

The clearance between the inner surface of the sleeve and the outer surfaces of the pipes is to be packed with heated cable (bituminous) compound MB, bitumen No. 5, asphalt-bituminous varnish, or rubber adhesive. When inserting pipes

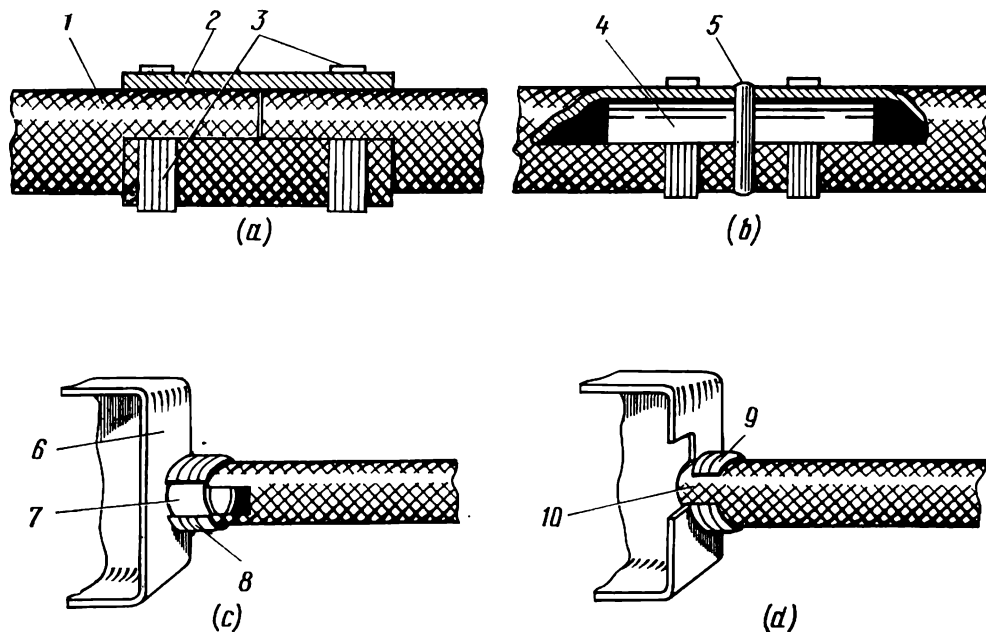


Fig. 64. Jointing bitumen-treated rubber pipes

a—two pipes are joined together through a sleeve; b—two pipes are joined together through a sleeve and a retaining ring; c—a pipe is joined to a pipe union of a box through an insulating tape band; d—a pipe is joined to a plastic box by inserting it into the box; 1—bitumen-treated rubber pipe; 2—sleeve; 3—wire bands; 4—thin-walled steel pipe length; 5—retaining ring; 6—junction or branch box; 7—pipe union; 8—insulating tape band; 9—tarred tape band; 10—bitumen-treated rubber pipe end inserted

into a sleeve, care shall be taken to ensure a tight fit between the ends of the pipes. To provide for a more reliable connection, the sleeve is to be covered at the ends (at a distance of 10 mm from the butt ends) with zinc-plated wire bands, the wire diameter being 1 to 1.5 mm. Bitumen-treated rubber pipes can also be joined together by means of a sleeve made of a thin-walled steel pipe length (Fig. 64b). The sleeve shall be 100 to 120 mm long, and a retaining ring of dia 2 or 3 mm wire is to be welded at its centre. The inner edges of the steel sleeve are to be reamed out so that it should not interfere with drawing the conductors into the pipe. Bitumen-treated rubber pipes are to be fitted onto the steel sleeve until they are stopped by the retaining ring, whereupon the joints are to be packed with bituminous compound, bitumen, or adhesive.

Where conductors laid in bitumen-treated rubber pipes go outside, for instance, out of foundations or flooring, they are to be covered with a steel pipe length or elbow and the joints are to be appropriately sealed.

Bitumen-treated rubber pipes brought out through foundations or floors onto incombustible walls are to be protected against mechanical damage at a height of up to 1.5 m with the aid of angle steel or a metal trough.

Bitumen-treated rubber pipes are to be connected to steel junction and branch boxes through expanded pipe unions made of thin-walled steel pipes welded to the box (Fig. 64c). The pipe is to be pulled onto the steel pipe union of the box and fixed in position by an insulating tape band.

A pipe brought into a plastic box (Fig. 64d) must have at least 10 mm of its length within the box. The clearance at the pipe entry is to be packed with conically wound resin tape.

5.8.3. Concealed Wiring in Plastic Pipes

Plastic pipes (preferably vinyl ones) have recently found wide application in wiring over combustible, almost incombustible, and incombustible building components in dry, humid, moist, extra moist, and dusty locations, in atmospheres containing chemically active agents, and in outdoor wiring systems.

When routed over combustible surfaces, vinyl plastic pipes shall be laid on asbestos sheets, at least 3 mm thick, or on a scratch coat, at least 5 mm thick, protruding at least 5 mm on either side from under the pipe, the pipe being then covered with a layer of plaster stuff, at least 10 mm thick.

In fire- and explosion-hazard locations vinyl plastic pipes shall never be used for wiring.

Wiring in plastic pipes is usually made in the same way as in paper-metal pipes.

Plastic pipes are joined together by means of plastic sleeves or the end of one of the pipes is made in the form of a funnel to receive the other pipe, the inner diameter of the funnel corresponding to the outer diameter of the other pipe being joined.

A rather high cost of plastic pipes sets limits on their wide use in wiring practice.

A finished concealed wiring system is to be tested with a 1000-V megger for open circuits, for proper jointing and splicing of conductors, and for conductor insulation resistance relative to earthed metal parts of the wiring system.

5.9. Jointing, Splicing, and Termination of Aluminium and Copper Conductors

A reliable operation of electrical installations greatly depends on proper jointing, splicing and termination of conductors.

The joints must be mechanically strong, have a low electrical resistance, and sustain frequent temperature gradients due to abrupt changes in supply load currents. These requirements can be met through a strict adherence to specified wiring technique and proper selection of parts and tools to be used for the purpose.

The most widely used methods of connection and termination of aluminium and copper conductors are compression and welding (electric, gas, or thermit weld-

ing). Soldering is also sometimes used, but it is a time consuming job requiring expensive solders, though soldered joints are sufficiently strong.

The choice of a method for the jointing, splicing, or termination of conductors primarily depends on the conductor material (aluminium or copper), because physical properties of aluminium greatly differ from those of copper.

Most wiring systems are made nowadays of aluminium conductors, because aluminium is a less critical material, aluminium-conductor wires and cables are cheaper and their mass is lighter. Aluminium, however, requires special techniques, due to some of its physical and mechanical properties, in joining aluminium-to-aluminium and aluminium-to-copper conductors and contacts.

One of the disadvantages of aluminium is its rapid oxidation, when in contact with air. A high-melting oxide film (its melting point is about 2000°C) formed on its surface is a poor conductor and interferes with making a good contact. Besides, when in contact with copper, aluminium forms a "galvanic pair" in which aluminium rapidly deteriorates under the effect of contact corrosion with the result that the joint is impaired. In order to prevent the deterioration of the joint, aluminium is protected against oxidation by coating the joint in the course of connection with quartz-vaseline or zinc-vaseline compound, and the finished joint is covered with an asphalt, glyphthalic, or polyvinyl-chloride varnish.

Hard particles contained in the compound destroy oxide films formed on the contacting surfaces, and vaseline isolates them from surrounding air, thereby preventing the formation of oxide films on them.

5.9.1. Connection of Aluminium Conductors to Terminals of Devices

On-off and change-over switches, plug connectors, and miscellaneous devices rated at 6, 10, and 15 A are furnished with terminals suitable for the connection of not only copper, but also aluminium conductors of up to 4 mm^2 sectional area. Each terminal is fitted with a spring washer or

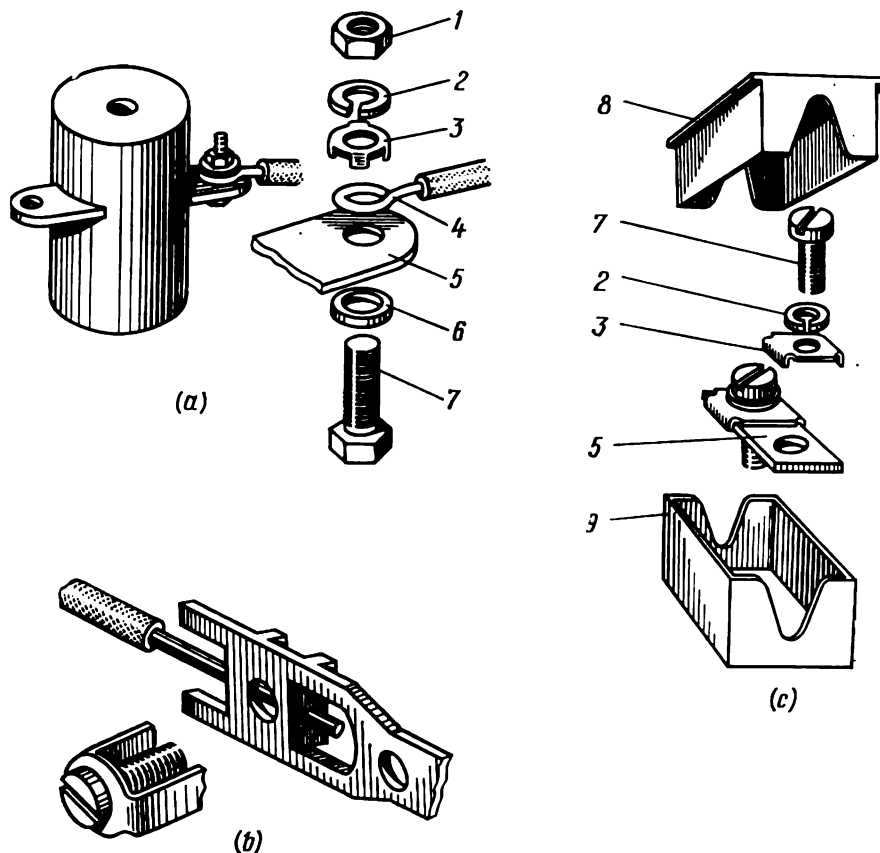


Fig. 65. Connection of single aluminium conductors

a—to flat copper terminal; b—to CO meter terminal; c—to candelier terminal; 1—nut; 2—hold-down washer; 3—sprocket washer; 4—wire loop; 5—flat copper lead (busbar); 6—washer; 7—binding screw; 8—upper part of insulating shroud; 9—lower part of insulating shroud

a sprocket washer that ensures a permanent contact pressure and prevents the conductor from coming loose.

Single-conductor aluminium wires are to be connected to copper terminals as is shown by Fig. 65a, b; connection of these wires to a stranded copper conductor of fitting wire through a candelier terminal is illustrated by Fig. 65c.

5.9.2. Jointing and Splicing of Single-Conductor Aluminium Wires and Cables of up to 10 mm² Area by Compression

Single aluminium conductors of up to 10 mm² area are to be joined and spliced by compression with the aid of aluminium sleeves. This is done by indentation at one or more points with the aid of the ПК-2М pliers or the ГKM hydraulic pliers.

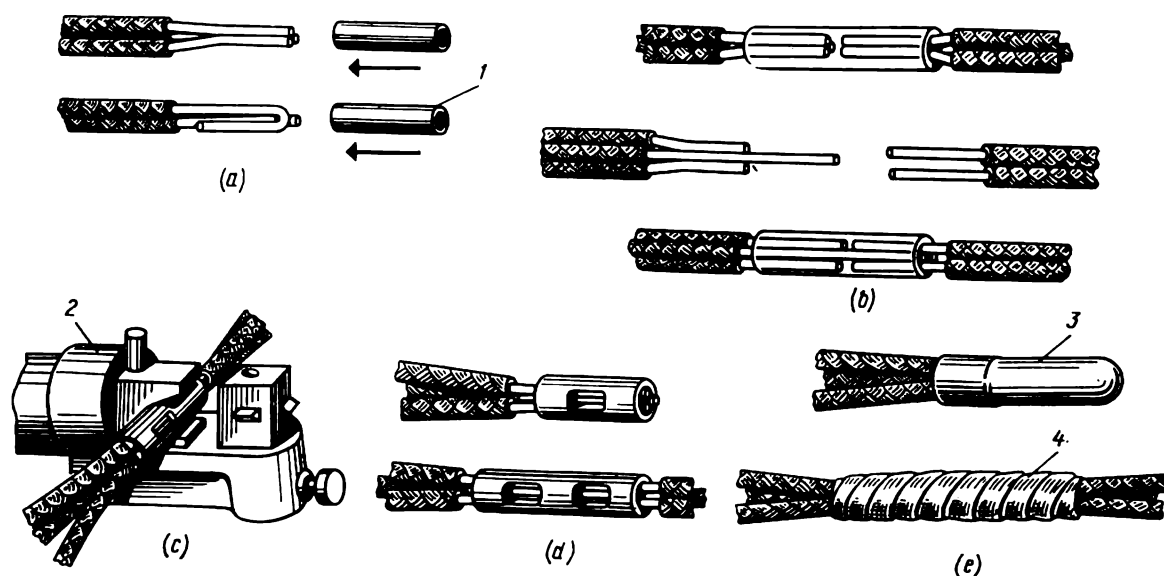


Fig. 66. Jointing single aluminium conductors by indentation in a sleeve

a—preparing conductors for single-ended indentation; b—same for double-ended indentation; c—indentation of conductors by ГKM pliers; d—compressed joints; e—finished joints; 1—ГАО sleeve; 2—ГKM pliers; 3—plastic cap; 4—PVC adhesive tape

After indentation the joint is to be coated with a layer of asphalt or glyphthalic varnish and insulated with adhesive tape (half the tape width overlapping), this procedure being followed by applying one more coat of varnish to prevent the admission of air and moisture to the contacting surfaces. Figure 66a through e illustrates compression of conductors by means of the ГKM pliers.

In compressing aluminium conductors, use shall be made of quartz-vaseline or zinc-vaseline compound. Zinc-vaseline compound is a toxic material and shall be kept away from food, injured skin, cornea.

5.9.3. Jointing and Splicing of Single Aluminium Conductors of 2.5 to 10 mm² Area by Welding and Soldering

Soldered joints are rather strong and reliable, but take much time to make them. Type A solder is to be used for aluminium.

Conductors are skinned at the ends to be joined, thoroughly cleaned off with a steel brush or a knife, and lap joined in a double lay so as to form a groove, as is shown by Fig. 67a. Then the conductors are heated with a torch or a gas burner to a temperature approaching the melting point of aluminium (860°C) and the surfaces to be connected are rubbed with a solder rod to remove high-heat oxide film formed on the conductor surface. The melting solder must fill the groove between the conductors. After having soldered the conductor on one side, the operation is repeated on the other side of the conductor.

The soldered joint is wiped with a clean rag moistened with petrol and then coated with a layer of glyphthalic or polyvinylchloride varnish and insulated with adhesive tape. The insulated joint is coated with a single layer of varnish.

USSR building standards and regulations (CHMΠ, Chapter VI "Electrical Installations") recommend jointing and splicing aluminium conductors of 2.5 to 10 mm² area by welding.

Electric welding is made in a casing by means of a welding gun and carbon electrodes, with flux or without flux.

For *welding without flux* (Fig. 67b), skinned and cleaned off conductor ends are indented by means of the welding gun in a casing made of a steel strip measuring 20 × 160 mm, 0.8 to 1 mm thick, so that the ends of conductors to be welded jut out of the casing by 3 or 4 mm. The conductor ends are then welded in an arc formed between the carbon electrodes of the gun connected to a welding transformer. After the metal has cooled down, the casing is removed, the joint cleaned off with a steel wire brush and coated with glyphthalic or asphalt varnish; the conductors must then be straightened (in the case of open wiring) and the joint must be covered with insulating tape or a vinyl cap, whereupon another coat of varnish is applied.

The only difference in *welding with flux* is that the conductor ends to be joined are twisted together, coated with flux and welded in an arc flame between the carbon electrodes of the welding gun without using a casing.

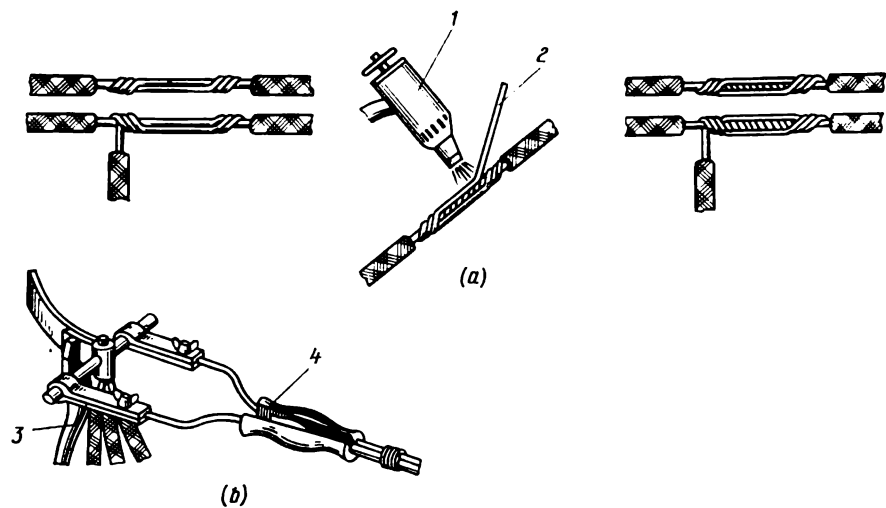


Fig. 67. Jointing aluminium conductors of up to 10 mm² sectional area

a—by soldering; b—by welding in a casing with the aid of carbon electrode welding gun; 1—gas burner; 2—solder stick; 3—pliers; 4—carbon electrode welding gun

5.9.4. Jointing and Splicing of Stranded Aluminium Conductors of Large Sectional Areas

Stranded aluminium conductors of large cross-sectional areas (16 to 240 mm²) are to be butt welded by resistance or by thermit pressure.

Electric welding. The conductor end to be welded is skinned and flushed in petrol. The conductor is set vertically and both the halves of a split mould 4 (Fig. 68*a*) are placed on it and fixed in position by means of a steel clip 5 or a wire band. The top edges of the mould must jut 1 to 2 mm over the butt end of the conductor

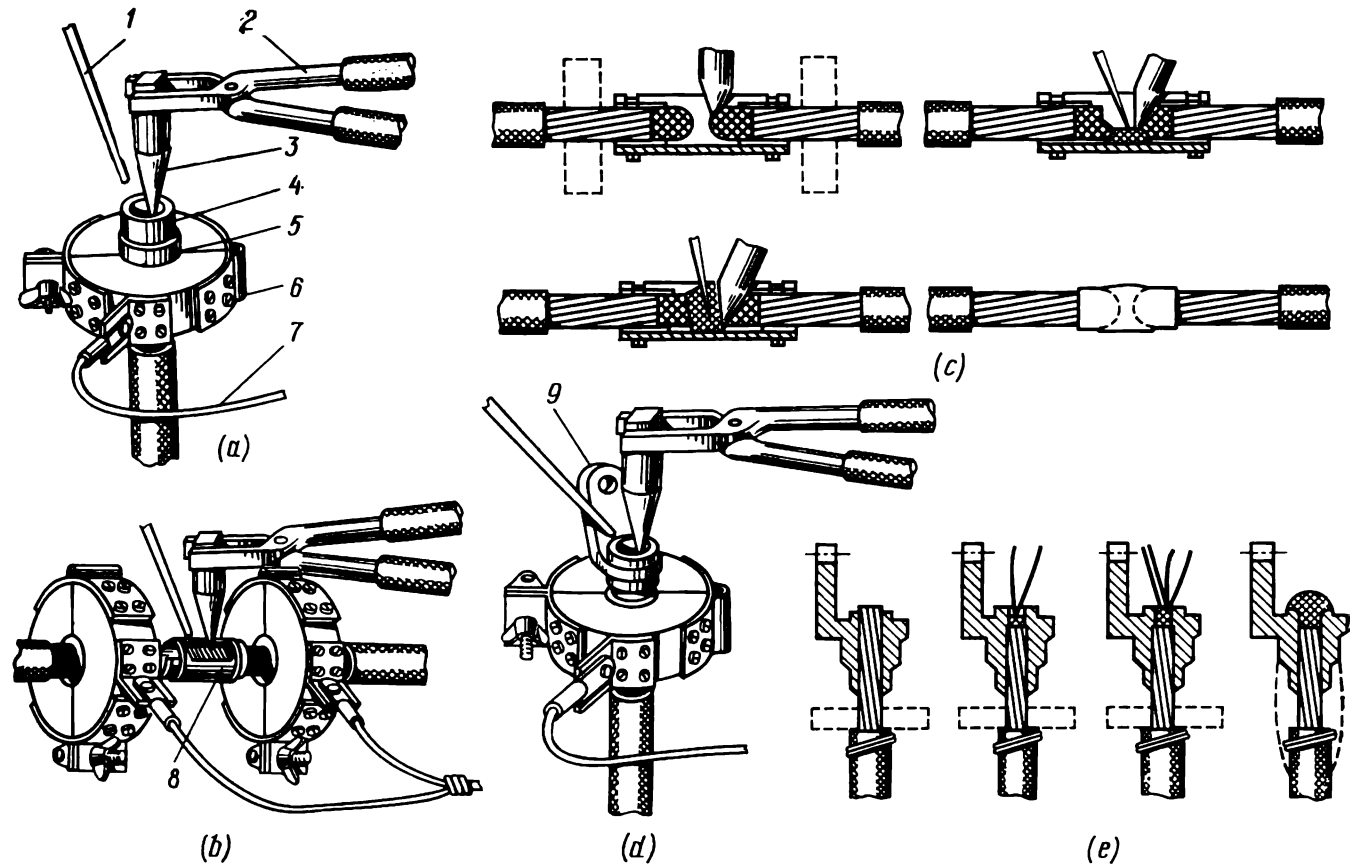


Fig. 68. Resistance butt welding and termination of stranded aluminium conductors for conductor sectional areas of 16 to 240 mm²

a—welding conductor end to obtain a solid joint; *b*—setting the conductors in a mould for butt welding; *c*—welding of conductors; *d*—preparing the conductor for termination with a lug; *e*—welding sequence when terminating stranded conductors with lugs; 1—welding rod; 2—electrode holder; 3—carbon electrode; 4—split mould; 5—steel clip; 6—cooler; 7—wire connecting the cooler to welding transformer; 8—groove mould for welding together aluminium conductors; 9—lug

to be welded and the bottom part of the mould is additionally tied up with asbestos cord, dia 1 to 1.5 mm. A cooler 6 is to be fixed directly under the mould on a skinned portion of the conductor. The wire leads running from the electrode holder and the cooler are connected to a welding transformer whose capacity must be minimum 1.5 kVA. Before welding, the butt end of the conductor is coated with flux. For welding, the carbon electrode 3 mounted in the electrode holder 2 is pressed to the butt end of the conductor and maintained so till the conductor acqui-

res a sufficiently high temperature and starts melting. For the further operations, the electrode is slowly moved over the conductor butt end to fuse all the strands of the conductor, and an aluminium welding rod *I* coated with flux is inserted into the fused conductor.

The welding rod melts and completely fills the mould. After the metal has cooled down, the mould and the cooler are removed from the conductor and the solid welded end of the latter is cleaned of remaining flux and slag with a steel brush. The conductor ends thus prepared for welding are coated with flux and placed between the butt ends of a horizontally mounted jointing or splice fillet mould leaving a small clearance between the conductors. The mould is then fixed to the conductors with a wire. Coolers are fitted on skinned portions of the conductors on both ends of the mould 8 and connected to the welding transformer (Fig. 68*b*). The conductors are melted by touching their butt ends, one after another, with the electrode, whereupon a flux-coated welding rod is brought into the mould and also melted. The procedure shall be continued until molten aluminium completely fills the mould and forms a spherical cup, 1 to 2 mm high, over the mould. After the mould and the coolers are removed, the welded portion is filed off, coated with asphalt or glyphthalic varnish, insulated, and coated with varnish again. The welding procedure is shown by Fig. 68*c*.

For terminating a stranded aluminium conductor by welding, the lug is fitted on the conductor so that the latter juts 2 or 3 mm out of the lug (Fig. 68*d*), whereupon the two parts are welded together as is illustrated by Fig. 68*e*.

Thermit welding. Thermit welding of stranded aluminium conductors is made in a thermit cartridge consisting of a thermit muffle and a steel chill.

Prior to welding in a thermit cartridge skin the conductor ends to be joined over a length depending on their cross-sectional area:

Conductor area, mm ²	Length of skinned portion, mm
16 and 25	50
35 and 50	55
70	60
95 and 120	65
150 and 185	70
240	75

Wipe the conductors with a rag and coat them and the welding rod with a layer of flux BAMИ diluted in water to a paste-like compound. Then fit aluminium caps or bushes on the conductor ends so as to prevent surface fusion or burning of separate outer layer strands. Put on the thermit muffle and the chill and pack the points where the conductors enter the cartridge with asbestos cord to prevent the escape of molten metal.

Fit chilling pliers on the skinned portions of the conductors to prevent overheating. Mount the thermit cartridge in a thermit welding machine. Fix a special match on a steel wire, 350 to 400 mm long, before starting the operation so as in burning to afford a temperature approaching 1000°C. The burning match fires the muffle and, hence, the cartridge, and while the latter burns, the conductors are welded together.

5.9.5. Jointing and Termination of Copper Conductors of 1 to 10 mm² Area

For the connection of single copper conductors having a cross-sectional area of 1 to 2.5 mm² to the terminals of instruments and devices, the conductor end to be connected is looped, the diameter of the loop being slightly larger than that of the binding post, or the skinned end of the conductor is inserted into the contact device of the piece of equipment being connected and fixed therein with a hold-down screw.

A stranded copper conductor of up to 2.5 mm² area is connected to a terminal as follows: the conductor lead is looped, the loop is run over with tin or compressed

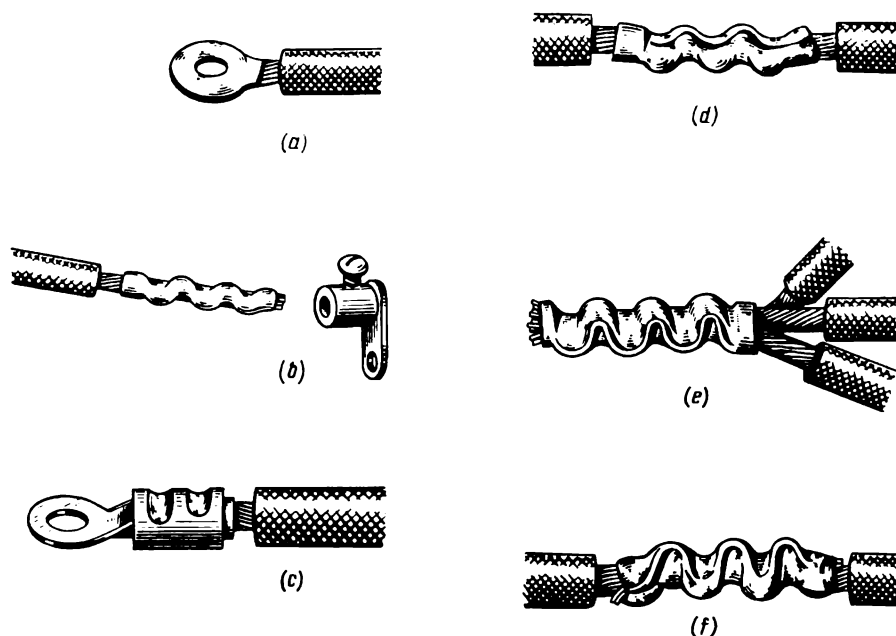


Fig. 69. Termination, jointing, and splicing of copper conductors up to 10 mm² in cross-sectional area

a—termination with a circular lug; *b*—termination by indentation and copper foil; *c*—termination with a lug by local indentation; *d*—jointing by local indentation in a single pass of a four-projection punch; *e*—splicing by local indentation in two passes of a two-projection punch; *f*—jointing by local indentation in five passes of a single-projection punch

in a circular lug (Fig. 69*a*). If the piece of equipment being connected has a terminal in the form of a cylinder with a hole and a hold-down screw, the stranded conductor lead is dressed by running over with tin or by indenting the lead wrapped in a single layer of copper foil, 0.15 to 0.2 mm thick (Fig. 69*b*).

Stranded copper conductors 4, 6, and 10 mm² in cross section are terminated with a circular lug, as shown in Fig. 69*c*, by transversely indenting its tubular portion with ПК-2М pliers. The skinned end of the wire conductor must be as long as the cylindrical portion of the lug plus 2 mm, or plus 10 mm for the cable conductor (to allow for subsequent sealing).

Jointing and splicing of stranded copper conductors are made by indentation of a jointing sleeve in a single pass (Fig. 69*d*) by means of a four-projection punch, in two passes (Fig. 69*e*) by means of a two-projection punch, or in five passes (Fig. 69*f*) by means of a single-projection punch.

Sizes and design forms of cable lugs and sleeves, and those of punches and dies are selected from appropriate tables of reference books, depending on the cross-sectional areas of conductors.

5.9.6. Connection and Termination of TИПФ and АТИПФ Wires

Conductors of the TИПФ and АТИПФ wires are connected in a box. Before inserting a wire into a box, the wire sheath is removed over a length of 5 or 6 mm so that 3 or 4 mm of the stripped wire end protrudes within the box. The wire end to be inserted into the box is covered at a distance of 8 to 10 mm from the shield with an unbleached thread or insulating tape band over a length of 8 to 10 mm, whereupon the overall band insulation is removed, the wire brought into the box, and the skinned conductors are interconnected by indentation or connected to the box terminals.

The TИПФ wire lead brought to a distribution board or a device is terminated with a steel tube of a diameter slightly larger than that of the wire and a porcelain bushing is fitted on the tube end. The terminating device is fitted on the TИПФ wire lead and secured to the supporting surface with a two-lug clip.

5.10. Installation of Lighting Fixtures, Devices, and Switchgear of Lighting Systems

5.10.1. Installation of Lighting Fixtures and Devices

Lighting fixtures, on/off and change-over switches, plug connectors, and other devices are to be mounted only after all the finishing and painting jobs are completed.

Lighting fixtures supplied on site complete with connecting wires shall be checked, phase, neutral, and vacant leads discriminated, whereupon the lighting fixture is to be attached to a mounting hook or bracket.

Lighting fixtures supplied without connecting wires shall be wired with special fitting wires, preferably flexible copper wires of appropriate types and cross-sectional areas, such as ПРКБ, ПРББ, etc. In wiring the lighting fixtures, the phase or vacant wire leads are to be connected to the heads (central contacts) of the lamp holders, and the neutral leads to their screw sleeves. The wires shall not be too heavily tensioned to prevent their break or coming off the contacts.

The lead-in arrangement for a lighting fixture depends on the type of the latter and the method of wiring used. Most lead-in arrangements of lighting fixtures are furnished with threaded fittings for the connection of steel wiring conduits to them. Lighting fittings meant for use in humid locations, in atmospheres saturated with chemically active vapours and gases, and outdoors in the case of an open wiring system (on knobs or insulators), have two holes for separate entry of conductors. The lead-in arrangements of lighting fixtures meant for the connection to a cable (type ЦПГ, БПГ, etc.) are provided with glands. If glands are not provided, the lead-in arrangement must be sealed by potting compound.

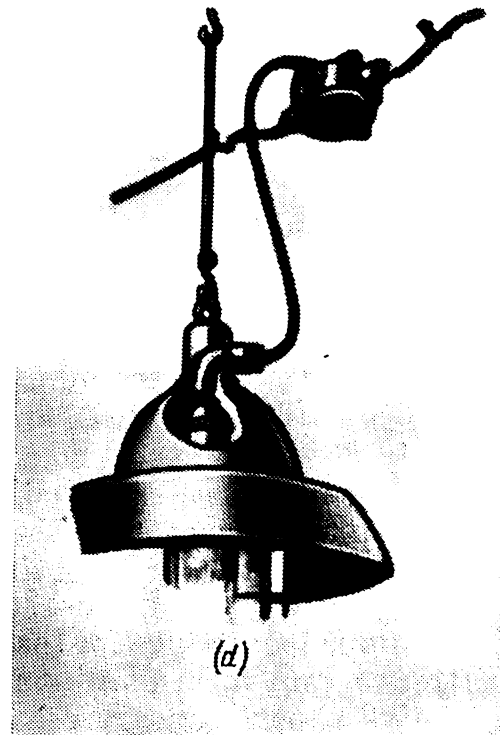
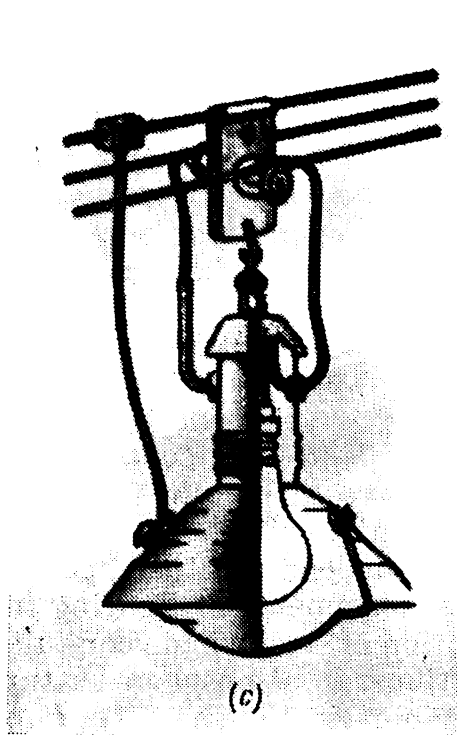
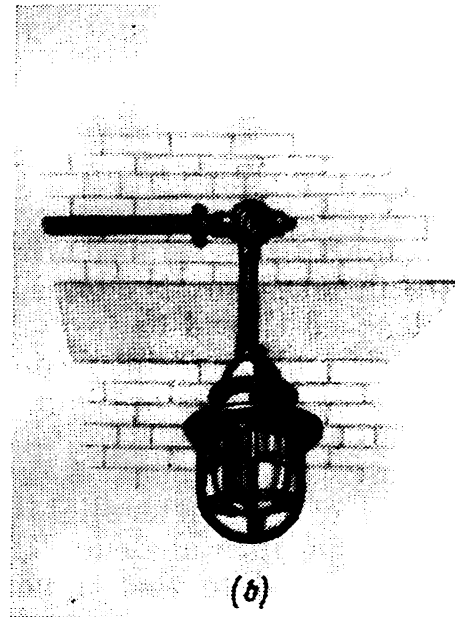
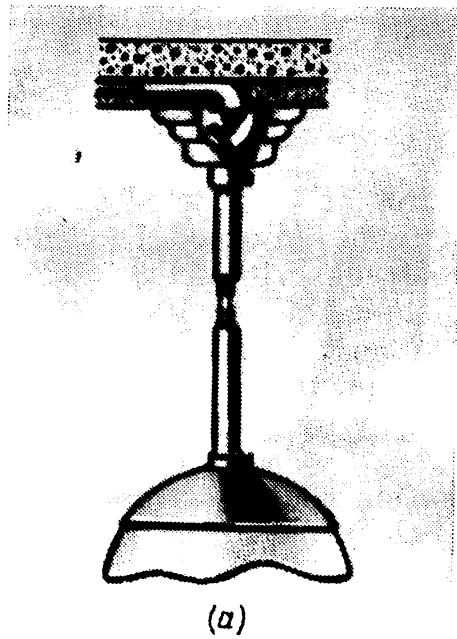


Fig. 70. Attachment of lighting fixtures with different methods of wiring
a—with concealed wiring; b—with open wiring in conduits; c—with catenary wiring; d—with wiring using cable ABPT

The lighting fixtures and supporting rods are insulated from mounting hooks and brackets by means of porcelain or press-board fittings, or covered with two layers of insulating tape.

Lighting fixtures made in the form of dome lamps, sconces, wall- and ceiling-mounted lamp sockets, are to be mounted on wooden rosettes, 10 to 12 mm thick, fixed on the wall or ceiling.

Where a lighting system is wired with tubular shielded wire АТПФ, the lighting fixtures must be rigidly fixed in position (for instance, on a steel supporting rod). Figure 70 shows how lighting fixtures can be mounted in different locations and with different methods of wiring.

On/off and change-over switches and socket outlets are to be mounted depending on their design form and the type of wiring used (Fig. 71).

Single-pole on/off and change-over switches are to be connected in series with the phase leads of wires and cables.

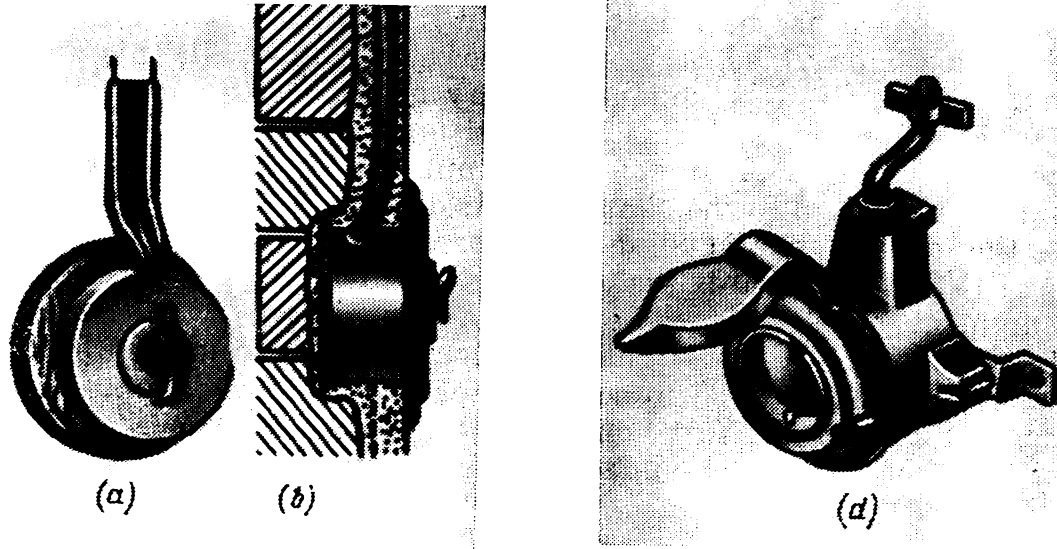


Fig. 71. Installation of circuit-opening devices and outlets

a—on/off switches for open wiring with АППБ wires; *b*—socket outlets for concealed wiring in half-hard rubber pipes; *c* and *d*—on/off switch and socket outlet for wiring with БП cable in moist location

Metal shrouds of switches and plug sockets shall be earthed by connecting them to the neutral conductor of the wiring system via a separate conductor, one of its ends being soldered or welded to the neutral conductor and the other connected to a special earthing screw fitted on the device shroud.

5.10.2. Switchgear Installation

Distribution boards are to be mounted in places convenient for their inspection and replacement of fuses. In residential buildings they shall be mounted at a height of 1.5 to 1.8 m, and in industrial premises they shall be installed in special recesses at a height of 1.2 to 1.4 m.

Bare current-carrying parts of the board are to be spaced at least 15 mm from incombustible walls (brick, concrete) and at least 50 mm from wooden walls. These clearances may actually be made as large as 100 mm and larger still to facilitate wiring and maintenance operations. Large distribution boards measuring 600×500 mm or more shall be spaced at least 250 mm from the wall.

Clearances between live bare parts of the board and its non-current-carrying metal parts shall be at least 12 mm in air and 20 mm over insulation surface.

Distribution boards are usually accommodated in steel boxes provided with locking steel or glass doors. Vacant lead-in holes of the boxes must be plugged.

Distribution boards shall never be mounted above door or window apertures.

Insulating bushings are to be inserted into the face and side holes of the boards for passing wires.

Appropriate inscriptions shall be made on the boards to indicate the number and purpose of each outgoing line or the name of factory shops where it runs (for example, "Emergency lighting of shop, No. 6", "Staircase lighting", "Lighting for 2nd floor of factory management", etc.).

Conductors of branch-circuit lines are to be connected to the fuse contacts after the distribution board has been installed and fixed in position. Sometimes, where a small clearance is provided between the board and the wall, this procedure may be changed, that is, first the conductors may be connected to fuses and then the board is to be mounted and fixed in position.

Conductors of supply and branch-circuit outgoing lines are to be connected on the rear side of the board to the contact leads of fuses, their phase leads being connected to the central contacts of the fuses.

The type IIIYЭ storey boards are used in 380/220-V network for the distribution and measurement of electric power within one floor.

Separate branch circuits of a lighting system running from the IIIYЭ board are to be connected or disconnected by means of packet switches mounted in a separate compartment of the board. Watt-hour meters are to be observed and circuit breakers and switches of the board controlled through special windows with the doors closed.

Distribution boards are preassembled at the factory and delivered to the installation site in packing cases. The packing cases shall be opened carefully avoiding damage to devices incorporated in the boards.

The IIIYЭ distribution board is meant for installation in a recess measuring 900×450 mm, 200 mm deep. The board is furnished with special terminals (Y730) suitable for the connection of both copper and aluminium conductors of up to 35 mm² area.

Installation of preassembled distribution boards and boxes is to be started with mounting them on a bedframe prepared during the construction work. Distribution

boards and boxes must be mounted in a strictly vertical position and rigidly fixed to a bedframe, wall, or any other building component, in compliance with the project and manufacturer's instructions.

Before mounting distribution boards incorporating ammeters, voltmeters, and other meters, these instruments are to be removed to avoid damage to them because of shocks indispensable in mounting, adjusting, and fixing the distribution boards.

Upon installation, all the previously removed instruments shall be placed in their respective positions and all the elements of the distribution boards and boxes are to be checked for condition and for serviceability. Contact blades on knife switches must enter the jaws without knocks and with a force affording the desired contact pressure. The contact pressure shall be considered adequate if a feeler gauge 0.05 mm thick and 10 mm wide enters the clearance between the blade and the jaws through a depth of not greater than 6 mm.

The jaws of fuses must be tightly fitted to the contacting parts of cartridges. The cartridges must be reliably fixed in the jaws to prevent their falling out by gravity or under the action of electrodynamic forces occurring in the event of throughput short circuits.

The retainers of knife-switch operating mechanisms must operate trouble-free.

The initial and final points of monitoring and measuring instruments must be on the same straight line parallel to the longitudinal edges of their mounting panel.

The earthing busbar running from the earth circuit to the distribution board shall be reliably welded to the bedframe and welded or bolted to the switchgear unit frame.

The insulation resistance of the switchgear current-carrying parts, as measured with a 1,000-V megger relative to the earthed frame, shall not be lower than 0.5 MΩ.

If the check results are adequate, the switchgear unit is to be connected to supply and outgoing wires and cables, whereupon all the elements are to be examined again with outgoing circuits carrying load currents so as to check for hot spots.

While carrying out on-load examinations, it is vitally important to observe safety precautions. To reveal hot spots in contacts and other connections, use shall be made of thermal plugs rated at the respective melting points.

Review Questions

1. What artificial light sources do you know?
2. What tools are used for marking out the wiring path?
3. How are open lighting wiring systems installed on insulators?
4. What methods are used for the installation of tubular shielded wires, type АТПРФ?
5. What methods are used in concealed wiring?
6. What methods of connection of aluminium conductors do you know and how are these conductors connected?

Installation of Cable Lines

6.1. General

Cables are laid on supporting structures, in troughs (in tunnels, in industrial premises), over the walls of buildings and structures, in trenches and conduits (over an industrial plant or heavily populated territory).

The most popular and simple method is laying cables in trenches as this procedure reduces to digging out trenches and placing cables in them. A disadvantage of this method is that buried cables may be easily injured and accidents with persons carrying out earthwork near the cable run may occur.

Laying cables in asbocement or concrete conduits is a more reliable method, but it is more complicated and much more expensive. Moreover, the current-carrying capacity of cables laid in conduits is lower than that of exposed or buried cables due to worse cooling conditions.

Whatever the method used, the cable run is to be selected so as to ensure a minimum possible distance between the starting and finishing points of the line.

Cable lines are to be installed in strict compliance with reference documents showing the line route and the datum marks that indicate the difference in the levels of separate line sections (see Table 21).

**Permissible Differences in the Upper and Lower Levels of a
Cable Route for 1 to 10 kV Service**

Table 21

Cable characteristic	Permissible difference between levels (m) for cables rated at voltages, kV			
	lead sheathed		aluminium sheathed	
	1-3	6-10	1-3	6-10
With normally treated paper insulation:				
armoured	25	15	25	20
nonarmoured	20	15	25	20
With leanly treated paper insulation:				
armoured with bands in common sheath	100	100	Unlimited	
same with conductors separately lead-sheathed	300	300	—	—
With nondisplacing impregnating compound		Unlimited		
With PVC and rubber insulation		Unlimited		

Notes. 1. Permissible level differences specified in the table concern cases where cables are not terminated in special arrangements (such as, epoxy boxes or potheads) limiting the displacement of impregnating compound.

2. Level differences for treated paper-covered and aluminium-sheathed cables of 1 kV service are unlimited.

Permissible level differences specified by Table 21 shall be observed as they influence the displacement of the cable insulating compounds. The cable conductors are heated by the current they carry. In the process, thinning of their insulating compound and its irreversible displacement takes place. Of all the materials of the cable, the insulating compound possesses the highest coefficient of volumetric expansion. That is why, heating the cable conductors builds up excess pressure that may cause elongation of the cable sheath under certain conditions and increase its volume to a critical value. Moreover, in a cable laid vertically or in an inclined position the insulating compound runs off by gravity, with the result that it accumulates in an excessive amount at the lower portion of the cable and the voids formed at its upper portion become filled with gas inclusions. Such a displacement of the cable compound deteriorates insulation of the upper portion of the cable and raises pressure at its lower portion, thereby leading to elongation and even breakdown of the cable sheath. Of great importance is also the adherence to specified clearances between the cable lines and adjacent buildings, underground constructions, and utility systems of all kinds (water and gas conduits, sewer systems, heating system pipelines, etc.).

Clearances between the cable line and the foundations of buildings shall be at least 0.6 m and those between the power and communication cables, at least 0.5 m.

Cables shall never be laid in parallel to pipelines in the vertical plane.

In the horizontal plane, they may be routed in parallel to pipelines on condition that they are spaced at least 0.5 m from all pipelines, with the exception of petroleum oil, gas, and heat pipings, and at least 1.0 m from petroleum oil and gas pipelines.

Cables laid at shorter distances from pipelines (but not shorter than 0.25 m) shall be protected with asbocement or ceramic pipes.

Cables laid in parallel with pipelines shall be spaced at least 2 m from the latter. A shorter distance may be allowed provided the pipeline is covered with insulation that does not allow the earth near the cable run to heat more than 10°C above ambient during any season of the year.

A cable crossing a pipeline shall be spaced at least 0.5 m from the latter. When this is the case, the pipeline portion crossing the cable plus 2 m on either side of the extreme cables shall be insulated so that the temperature of the earth does not exceed the highest summer temperature by more than 10°C and the lowest winter temperature by more than 15°C.

Where cable lines cross electrified railways or those planned to be electrified, cables shall be laid in conduits or in pipes. The crossing section shall be spaced from switches, frogs, and points of connection of drain cables to rails at least 3 m for tram lines and non-electrified railways and at least 10 m for electrified railways.

Cable lines crossing pipelines, especially petroleum oil pipelines, shall be spaced at least 0.5 m from the latter. A shorter distance, down to 0.25 m, may be allowed on condition that cables are laid in a pipe protruding at least 2 m on either side.

Cable lines shall be laid within minimum time. Provision shall be made on the cable line installation site for safety of transport and pedestrians and for normal operation of enterprises. Therefore, prior to starting the work, it is essential to

thoroughly study all the reference technical documents, to examine the cable route and to spot the location of storage points for materials, tools, accessories, and mechanisms, foot-paths and transport roads to cross the cable route so that the required quantity of guards, warning signs, and foot-bridges could be prepared in advance.

All the main and auxiliary materials shall be delivered to the cable line installation site.

Each cable line shall be routed so that a definite amount of work be completed within a single day. So, upon digging out trenches, laying cables in them, and filling the trenches back not a single unearthed or empty trench shall be left.

6.2. Laying Cables in Trenches

Cable laying in trenches includes the following scope of work: preparatory work, digging out trenches, delivery of cable drums to the installation site, unreeling the cable and placing it in the trench, back filling of the trench.

Preparatory work includes the delivery of required amount of brick, sand or fine-grain sifted earth, steel and asbo cement pipes of at least 100 mm diameter for cable crossings under rail tracks, highways, and various obstacles encountered along the cable route.

Where a cable line crosses foot-paths, foot-bridges with rail bars shall be installed. Foot-bridges are to be delivered on site in advance.

Excavation work may be started only after checking against the plan or, if the latter is not available, by means of prospecting pits that there are no underground structures, utility pipelines, or other cables on the cable route or in close proximity to it. To this end, the plan shall be thoroughly examined for the location of underground constructions. In the absence of a plan, prospecting pits, 350 mm wide, are to be dug out across the marked-out cable route; pits are to be made with particular care so as not to damage cables, pipes, and various structures that may be buried nearby.

Long trenches are dug out by means of special rotor-type trench diggers or, more often, by standard digging machines or excavators.

Short trenches and those made under asphalt-covered footways, as well as trenches arranged in confined spaces where mechanisms cannot be used, are dug out manually with a crowbar and a spade.

Trenches shall be at least 700 mm deep and wide enough to ensure a spacing of at least 100 mm between adjacent parallel cables for up to 10 kV service and at least 50 mm between the trench wall and the extreme cable (Fig. 72*a* through *d*).

The depth of cable laying shall be reduced down to 0.5 m on line sections up to 5 m long where cables are brought into a building or cross other underground structures, with the cables being laid in asbo cement pipes to protect them against mechanical damage.

Where the cable route is curved, the trench is to be made so as to make it possible to lay the cable therein with the desired bending radius.

The bending radius of the cable shall be related to its diameter as a multiple of:

- (a) 25 for single-conductor power cables, treated paper-covered, lead-sheathed,

armoured and nonarmoured; for multiconductor power cables with leanly impregnated insulation and nondisplacing insulating compound, in a common lead or aluminium sheath, armoured; for multiconductor power cables, paper covered, with lead or aluminium sheathed conductors, and also with polyvinylchloride covered and sheathed conductors, armoured and nonarmoured;

(b) 15 for multiconductor power cables, treated paper-covered, lead or aluminium sheathed, or polyvinylchloride covered and sheathed, armoured and nonarmoured; for control cables, paper covered, lead sheathed, armoured and nonarmoured;

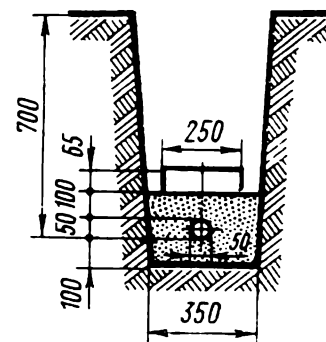
(c) 10 for power and control cables, rubber covered, lead or PVC sheathed, armoured.

Where cable jointing sleeves are expected to be located, the trenches shall be expanded to form pits. A pit for a single jointing sleeve to receive a cable for up to 10 kV service shall be 1.5 m wide and 2.5 m long. The pit to receive the next adjacent sleeve shall be made 350 mm wider.

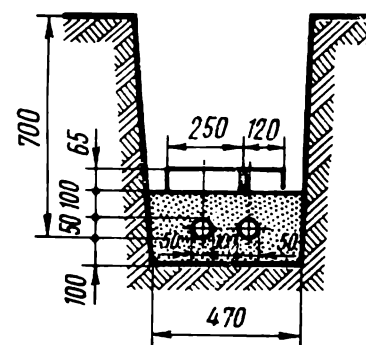
Cobblestones, lumps of asphalt and concrete dug out shall be placed on one side of the trench or pit at a distance of at least 1 m from its edge so that they were not in the way of workmen.

Cables are delivered on site wound on drums by means of special cable carriers or vehicles equipped with cable drum loading, transporting, and unloading mechanisms. Cable drums shall be unloaded carefully so as not to damage the cable or injure the workmen. Cable drums must never be thrown off cable vehicles or carriers. Cable drums must be unloaded at a minimum distance from the point of cable unreeling, but sufficient space shall be left for people moving along the trench; at the same time, the drum shall be positioned so as to ensure easy unreeling of cable.

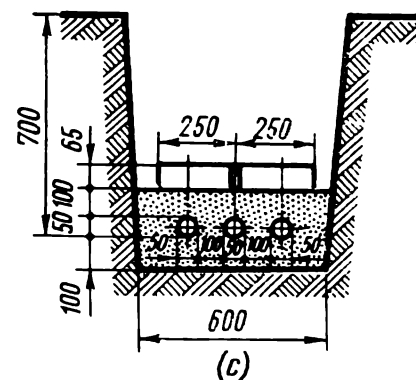
Cables delivered on site are reeled off the drums by means of cable laying vehicles, by winches over pulleys, manually over pulleys or without pulleys.



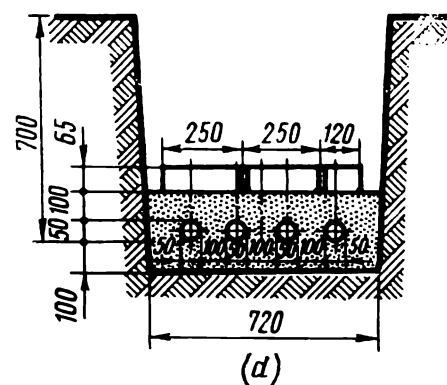
(a)



(b)



(c)



(d)

Fig. 72. Dimensions of cable trenches and arrangement of cables in them with bricks used to protect cables against mechanical damage

a—with one cable laid; b—with two cables laid; c—with three cables laid; d—with four cables laid

For reeling a cable off a drum mounted on a vehicle or on a hauled cable carrier, two men must rotate the drum manually to reel off the cable and the other two

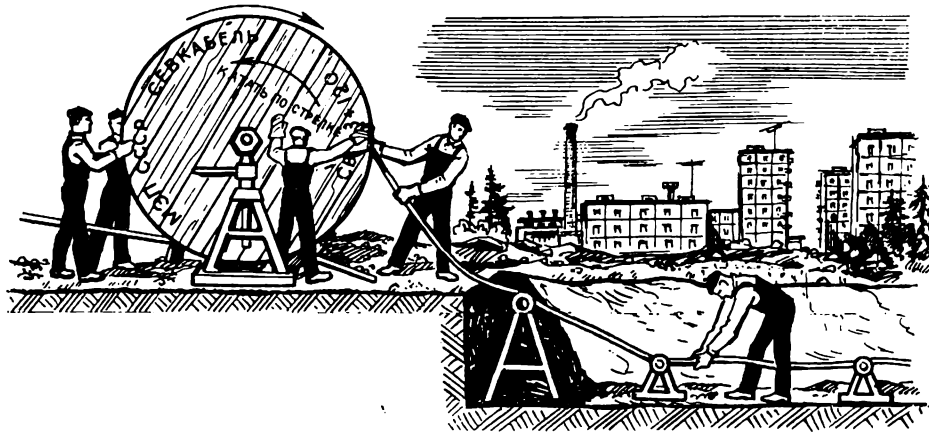


Fig. 73. Cable reeling off a jack-mounted drum by means of a winch

men must receive the cable and lay it in the trench. The cable is to be reeled off from the top and not from the bottom. The cable laying vehicle or carrier shall move at a speed not over 2.5 km per hour.

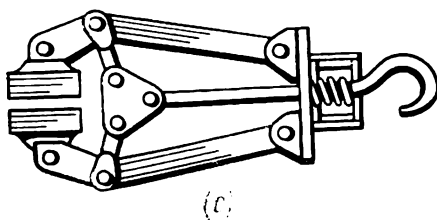
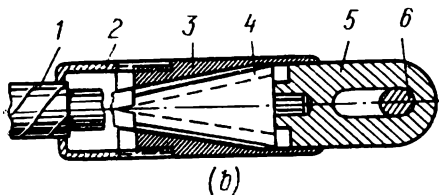
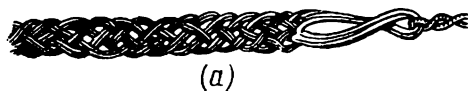


Fig. 74. Cable attachment to wire rope

a—wire sleeve; b—tapered clamp; c—lever-type clamp; 1—cable; 2—protective shroud; 3—external cone; 4—tapered sprocket; 5—steel head; 6—wire rope

To reel a cable off a drum mounted on the ground, the drum shall be elevated from the ground by 200 to 250 mm with the aid of a steel shaft and two cable jacks (Fig. 73). Wooden planks, at least 50 mm thick, bricks, or ferroconcrete slabs are to be fitted under the jacks.

Prior to unreeling the cable, linear and angle pulleys shall be mounted in the trench. Linear pulleys are mounted on straight sections of the line and spaced 2 m apart; angle rollers are placed where the trench is curved or makes a turn.

Just before unreeling the cable the drum must be cleaned of planks and the outer turns of the cable shall be examined for dents, damaged armour, or other defects. Then the steel wire rope is to be reeled off the winch drum and attached to the cable end. The cable to be unreeled is secured to the winch rope by means of a wire sleeve (Fig. 74a), a tapered clamp (Fig. 74b), or a lever-type clamp (Fig. 74c). The wire sleeve is to be fitted on the cable end and fixed in position on its length of at least 500 mm with the aid of three soft wire bands (wire diameter being 1.5 mm) applied on top of tarred tape covering. This method of attachment has a

number of drawbacks, the main ones being that much time is required to attach the cable to the winch rope, the sleeve may slip off the cable sheath,

and, finally, the cable sheath may be easily damaged near the sleeve.

A tapered clamp affords a more advanced method of attachment (Fig. 75). The clamp is fixed to the cable conductors. To this end, the clamp is disassembled, the cable sheath and the belt insulation are removed from the cable end on a length of about 200 mm, the conductors are stripped of paper insulation on a length

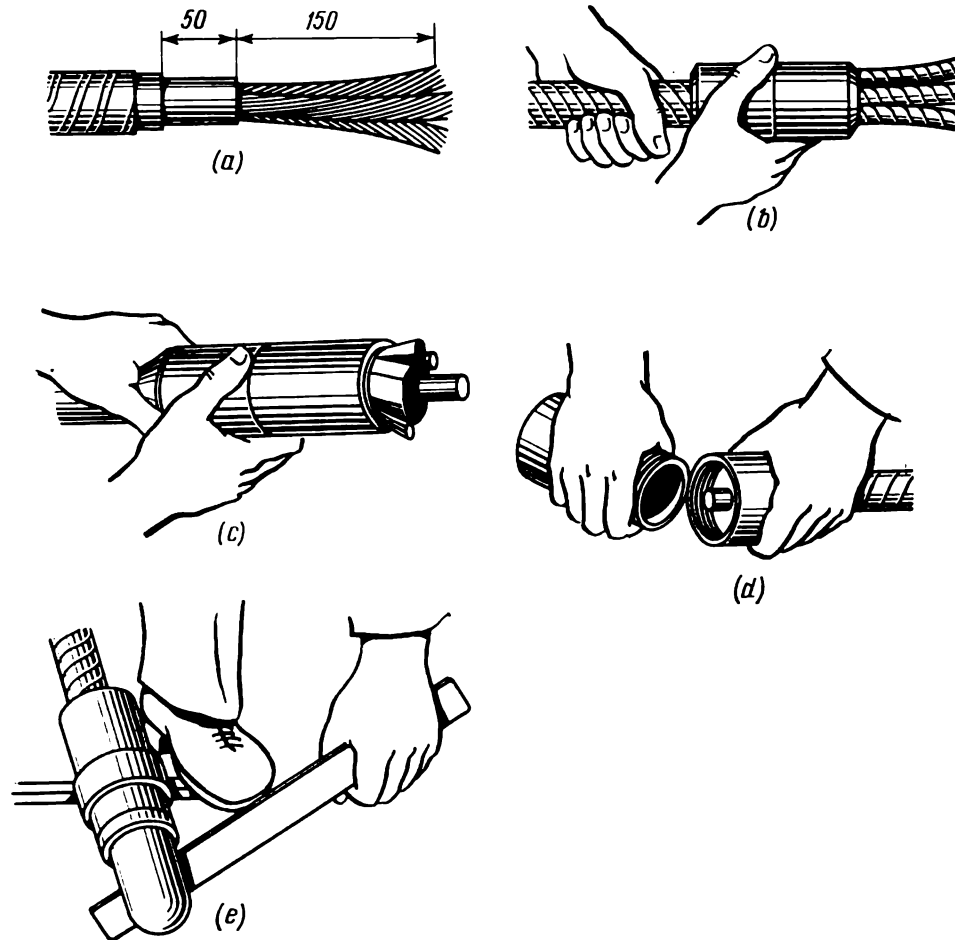


Fig. 75. Fitting a clamp on the end of a cable being reeled off (a, b, c, d, e—successive stages)

of about 150 mm, cleaned of remaining impregnating compound, and inserted into the clamp (Fig. 75b). Then a tapered sprocket (Fig. 75c) is inserted into the clamp shroud, its bore being selected to suit the conductor sectional area (Fig. 75d). The reassembled clamp is inserted into the clip and fixed therein with the aid of a locking bolt. The protective shroud is screwed onto the external cone, and then it is turned in with the aid of a steel tap wrench inserted in its head (Fig. 75e) until the cable conductors are tightly fixed between the external cone and the tapered sprocket. This done, the winch rope end is inserted into the oval opening of the clamp and secured therein. After that the winch drum is set in motion to unreel the cable.

To perform this procedure manually, the workmen place the cable on their shoulders and slowly move along the trench edge or along the bottom. The cable

being placed on shoulders shall not be sharply bent. Every workman engaged in the job shall not carry more than 35 kgf. The cable shall be placed on the same side, that is, it is to be supported by the like shoulders (right-hand or left-hand) of the workmen to avoid any injury when lowering the cable down on the ground. The cable is to be lowered simultaneously by all the men and in two steps, first down to the level of the wrists and then to the ground. The cable shall never be dropped onto the ground to prevent accidents and damage to the cable.

If the crew of workmen is not sufficiently strong to afford normal manual unreeling, a cable for up to 1 kV service may be unreeled (at a temperature of higher than 0°C) by the so-called loop method. To this end, the cable drum is placed in the centre of the trench and not at its beginning, a half of the cable is reeled off the drum from the top in one direction (as in the usual manual unreeling) and the other half is reeled off the drum from under its bottom in the opposite direction with a loop thrown over the drum.

When the loop method is used, care shall be taken to keep to permissible bending radius and to prevent spinning of the cable. The cable is to be laid in the trench in a wavy manner so as to provide for some spare length* that is required to compensate for longitudinal strain that may occur as a result of soil subsidence or temperature fluctuations. A spare length is also necessary to remedy the cable in the event of its break. When this occurs, the faulty section of the cable is cut out and a jointing sleeve is installed, the new connection requiring some extra length of the cable. A spare length shall never be obtained by laying the cable in circular turns as these turns may run hot after a short time in operation and the cable will fail very soon. A spare length can be obtained by laying the cable in an open loop at the end of the line, at vertical risers, at points where the cable is passed to the submerged route, etc.

The unreeled cable is to be taken off the pulleys and placed on the trench bottom. The pulleys are to be removed from the trench.

At the points of entry into, and exit from, the pipe the cable is to be wrapped in three or four layers of jute yarn to prevent damage by sharp edges of the pipe.

When more than one cable is to be laid in parallel, the ends of the cables and the jointing sleeves are to be staggered (Fig. 76a, b, c).

Once laid in the trench, the cable shall be checked for crossing clearances to nearby underground structures, whereupon a reference drawing of all the cable lines routed shall be drawn up where the location of each cable line with regard to permanent landmarks shall be indicated. If there are no permanent landmarks in the vicinity of the cable route, special bench marks shall be installed at all the cable turns and at sleeves; bench marks are to be also provided on straight sections of the cable route where they shall be spaced 100 to 150 m apart.

Each cable line shall bear an identification number or name indicated on labels that are to be attached to all the cable sleeves and terminations, and also at every 20 m on the straight portion of the line.

* A spare length obtained due to a wavy cable laying shall amount to 1-3 per cent of the total cable length. A shorter spare length may cause damage to the cable, but a larger spare length is not reasonable and will only be a waste of expensive material.

Labels are to be made in the form of plastic, aluminium, or steel plates of a circular shape, dia 75 mm, or of a rectangular shape measuring 120×40 mm. For making these labels, use is often made of pieces of PVC, vinyl, or lead remaining after cable making-off.

Rectangular labels are used for marking cables rated up to 1,000 V and circular ones for those of more than 1,000 V service. Labels are to be attached to cables and cable sleeves with the aid of zinc-plated wire, dia 1.5 to 2 mm, coated with bitumen to prevent corrosion. Labels attached to cables shall indicate the cable voltage, conductor cross-sectional area, line number or name; those fixed at cable sleeves at a distance of 100 to 150 mm from them are to show the sleeve number, date of its installation, and name of the electrician in charge.

Upon marking and final examination, the trench is to be filled back and the cables are to be protected. In the trench, the cables are to be covered with a 100-mm layer of soft sifted earth or sand, then a layer of bricks (except for silicate) shall be placed on top to protect the cables* against mechanical damage in future excavation work (Fig. 72). The trenches may be filled with earth taken out of them if it is free from stones, debris, lumps of slag, etc. Each layer of earth, maximum 200 to 250 mm thick, shall be moistened with water and rammed.

In cold seasons trenches are to be filled with dry sand or fine sifted earth. The earth excavated from the trench is not good for the purpose as it consists of frozen lumps that may damage the cable. Moreover, when a thaw sets in, the earth will subside over the entire cable route.

It is good practice to fill the top of the trench and to clean the cable route after filling by means of a power-operated earth mover. All the destroyed covers of factory territories, streets, and roads shall be recovered.

Cables with normally and poorly impregnated paper insulation and PVC covered cables may be laid in trenches only at an ambient temperature over 0°C . If

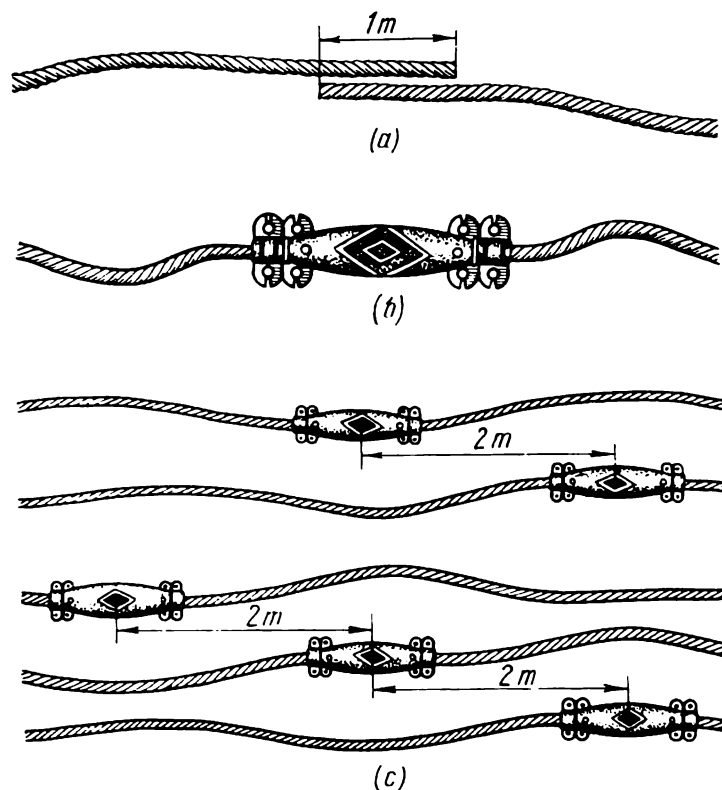


Fig. 76. Several cables with sleeves laid in parallel in one trench

a—position of cable ends to be joined together in a sleeve; b—cable extra length at sleeve installed; c—mutual position of several cables with sleeves mounted

* Cables for up to 1,000 V service are to be protected in this way only on sections within which mechanical damage may be expected, such as, where excavation work is frequently carried out.

the ambient temperature drops below zero at least for a short time within the day before the cable is laid, it will be necessary to heat the cable before placing it in the trench in heated premises, in a heated frost-protection enclosure, or by electric current. The time of exposure to heating temperature in heated premises or in

Table 22

Maximum Permissible Temperatures for Cable Conductors Heated by Special Transformers

Maximum permissible temperature, °C	Cable characteristics
60	Conductors of treated paper-covered cables for 10 kV service
65	Same of PVC or rubber covered cables for 6 kV service
80	Conductors of treated paper-covered cables for up to 3 kV service

- Notes. 1. The cable conductor temperature is checked by means of a thermometer (thermocouple) placed on the cable sheath.
 2. In heating the cable conductors with electric current it is essential to bear in mind that the temperature measured at the outer cable turns on the drum may differ from the actual temperature of conductors by 15 to 20°C. That is why one must cease heating as soon as the shroud temperature on the outer cable turns of the drum reaches 30 or 35°C.

a frost-protection enclosure depends on the ambient temperature and on the cross-sectional area and type of the cable. To ensure better heating conditions, the cable drum shall be cleaned of outer planking, lifted on jacks, and turned about its axis

Table 23

Parameters of Heating Three-Conductor Cables of up to 10 kV Service Wound on Drums

Conductor sectional area, mm ²	Maximum heating current, A	Supply voltage for 300-m cable, V	Approximate heating time, min, at ambient temperature, °C		
			0	-10	-20
10	76	69	60	75	95
16	102	58	60	75	100
25	130	48	70	90	105
35	160	42	75	95	110
50	190	34	90	110	135
70	230	30	100	120	130
95	285	27	105	125	160
120	330	25	115	140	170
150	375	22	125	150	185
185	425	18	135	170	210
240	490	16	150	190	240

- Notes. 1. For a cable longer than 300 m the supply voltage shall be raised in proportion to the cable length.
 2. The heating current of each cable phase shall be periodically measured with a hook-on ammeter. The heating current shall not exceed the rated values of current density specified for particular types and cross-sectional areas of cables.
 3. Heating currents, voltages, and time intervals are given as reference data only.

through 180 deg every 10 or 12 hours because the temperature in the upper and lower layers of air within the premises (frost-protection enclosure) always differs by a few degrees.

The most advanced and fast method of heating is by three-phase electric current supplied from a three-phase 20-kVA transformer connected to 220- or 380-V supply mains, with its secondary voltage varying in ten voltage steps from 7 to 98 V. The cable to be heated by electric current is to be suitably protected and the conductor leads on its internal end are shorted out for the time of heating, whereupon this cable end is sealed with a lead cap soldered on it. The external end of the cable wound on the drum is made off, terminated with an auxiliary diving box that is potted in bituminous compound. When more than one cable is to be heated and the cables are wound on separate drums, the conductors of these cables are connected in series via auxiliary wires. In the process, the temperature of the conductors is constantly checked for keeping within the values specified by Table 22.

Approximate data on the cable heating current, voltage, and time of heating are given in Table 23.

Heated cable must be laid in the trench within a definite time interval (Table 24).

Table 24

**Maximum Time Intervals within Which Heated Cables
Shall Be Laid in Trenches**

Ambient temperature, °C	Time, min
—5	120
—10	60
—20	30

Note. At temperatures lower than —20°C the cable must be permanently heated while being reeled off the drum and laid in the trench.

6.3. Laying Cables in Conduits, on Supporting Structures, and in Troughs

6.3.1. Laying Cables in Conduits

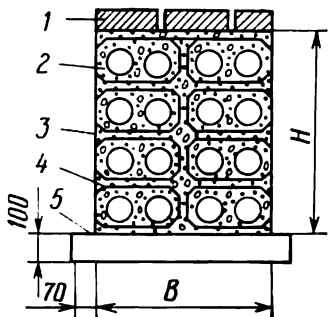
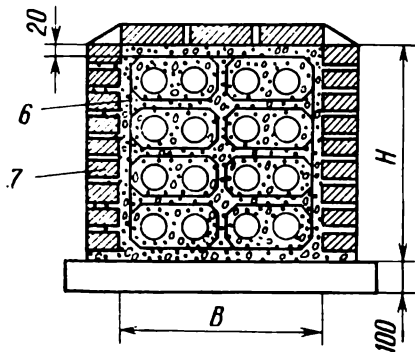
A cable conduit is an arrangement built in the ground and used to protect the underground cables against mechanical damage.

A conduit usually consists of a number of pipes (asbocement, ceramic, and the like) or ferroconcrete elements (panels) and associated manholes.

Conduits shall be delivered to the installation site and arranged along the cable route. Data on conduits made of ferroconcrete plates and pipes are given in Tables 25, 26, and 27.

Table 25

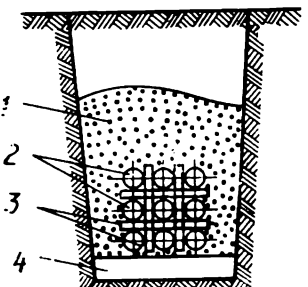
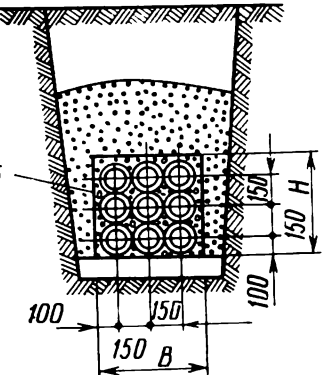
Dimensions of Cable Conduits Made of Ferroconcrete Panels

Ferroconcrete panel conduits	Conduit type	Number of ducts			Dimensions, mm	
		horizontal	vertical	total	B	H
	ББ-1/3 ББ-2/2 ББ-2/3	1	3 2 3	3 4 6	150/180	480/490 345/355 510/520
	ББ-2/4 ББ-2/6 ББ-2/8	2	4 6 8	8 12 16	300/300	675/685 1005/1015 1335/1345
<p>Dry soil</p> 	ББ-3/3 ББ-3/4 ББ-3/5 ББ-3/6 ББ-3/8	3	3 4 5 6 8	9 12 15 18 24	450/480	510/520 675/685 840/850 1005/1015 1335/1345
	ББ-4/4 ББ-4/5 ББ-4/6	4	4 5 6	16 20 24	615/645	675/685 840/850 1005/1015
<p>Moist and water-saturated soils:</p> <p>1—brick masonry; 2—panel; 3—cement mortar; 4—insulating bitumen; 5—concrete layer; 6—insulating cover; 7—brick wall</p>	ББ-5/5 ББ-5/6	5	5 6	25 30	765/795	840/850 1005/1015

- Notes. 1. Conduit dimensions B and H are given by fractions in which the numerator stands for conduits laid in dry soil, and the denominator for those laid in moist soil.
2. The ББ conduits are composed of two-duct or three-duct ferroconcrete panels, type ПК-2 and ПК-3, 5995 mm long, or type ПК-2a and ПК-3a, 2995 mm long.
3. The panel ducts must be finished so as to exclude any damage to the cables drawn therein. The inner surfaces of the ducts must be coated with type БН-IV bitumen diluted in paraffin oil in 2 : 1 proportion.

Table 26

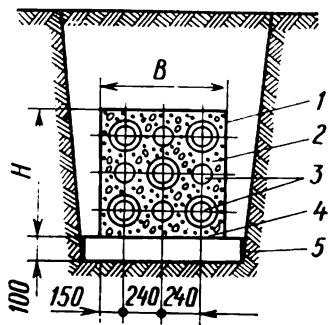
Dimensions of Cable Conduits Made of Asbocement Pipes

Asbocement pipe conduits	Type of conduit	Number of ducts			Dimensions, mm	
		horizontal	vertical	total	B	H
	БА-1 БА-1/3	1	1 3	1 3	200	200 500
	БА-2/2 БА-2/3 БА-2/6 БА-2/6 БА-2/8	2	2 3 4 6 8	4 6 8 12 16	350	350 500 650 950 1250
	БА-3/3 БА-3/4 БА-3/5 БА-3/6 БА-3/8	3	3 4 5 6 8	9 12 15 18 24	500	500 650 800 950 1250
	БА-4/4 БА-4/5 БА-4/6	4	4 5 6	16 20 24	650	650 800 950
	БА-5/5 БА-5/6	5	5 6	25 30	800	800 950
<p>Moist and water-saturated soils: 1—sand or sifted soil filler; 2—pipes; 3—wooden spacers; 4—concrete pad; 5—water-proof insulation</p> 						

- Notes. 1. For cable conduits use is made of asbocement pipes (for headless pipelines) with an effective passage of 100 or 125 mm.
2. When conduits are laid in dry soils, the outer surfaces of asbocement pipes shall be coated with two layers of water-proof insulation, and when they are laid in water-saturated soils, two layers of water-proof paper insulation shall be pasted on them.
3. The pipes are to be connected at the joints through asbocement or sheet steel collars, 150 to 200 mm long and 1 to 1.2 mm thick. The joints between the pipes shall be sealed with concrete and covered with suitable water-proof insulation.

Table 27

Dimensions of Cable Conduits Made of Ceramic Pipes

Ceramic pipe conduit for chemically active and water-saturated soils	Type of conduit	Number of ducts			Dimensions, mm	
		horizontal	vertical	total	B	H
 <p>1—water-proof insulation; 2—sealing the pipe joints with concrete; 3—ceramic pipes; 4—painting insulation; 5—concrete layer</p>	БК-1 БК-1/3	1	1 3	1 3	300	300 780
	БК-2/2 БК-2/3 БК-2/4 БК-2/6	2	2 3 4 6	4 6 8 12	540	540 780 1,080 1,500
	БК-3/3 БК-3/4 БК-3/5 БК-3/6	3	3 4 5 6	9 12 15 18	780	780 1,020 1,260 1,500
	БК-4/4 БК-4/5	4	4 5	16 20	1,020	1,020 1,260

Notes. 1. For conduits use is made of ceramic (sewage) pipes, inner dia 125 mm, and 1,000 and 1,200 mm long.
2. Wooden spacers are to be fitted across the horizontal rows of conduit pipes at a distance of 100 to 150 mm from the throats.

Each cable conduit must have up to 10 per cent vacant ducts or at least one vacant duct.

Conduits are to be buried in the ground at a depth depending on local conditions, but this depth must not be less than that permissible for cable laid in trenches.

Where the route changes its direction or the cable lines laid in conduits are branched off, manholes shall be arranged at the points where the cables leave the conduits and run into the ground (Fig. 77a through f) to facilitate pulling newly routed cables through the conduits and to easily replace faulty cables in the course of operation.

Conduits are to be laid with a downgrade towards the manholes at least 100 mm per every 100 m to provide for moisture drainage. Manholes on straight sections of the route are to be spaced apart depending on the local relief, completed length of cables laid, and permissible pulling force to be applied to the cable drawn into the conduit duct (Table 28).

The manholes are constructed so as to ensure normal conditions for cable laying and installation of cable sleeves and boxes. A water collector in the form of a hole covered with a metal screen is to be made at the bottom of the manhole to collect subsoil and storm waters that may infiltrate therein.

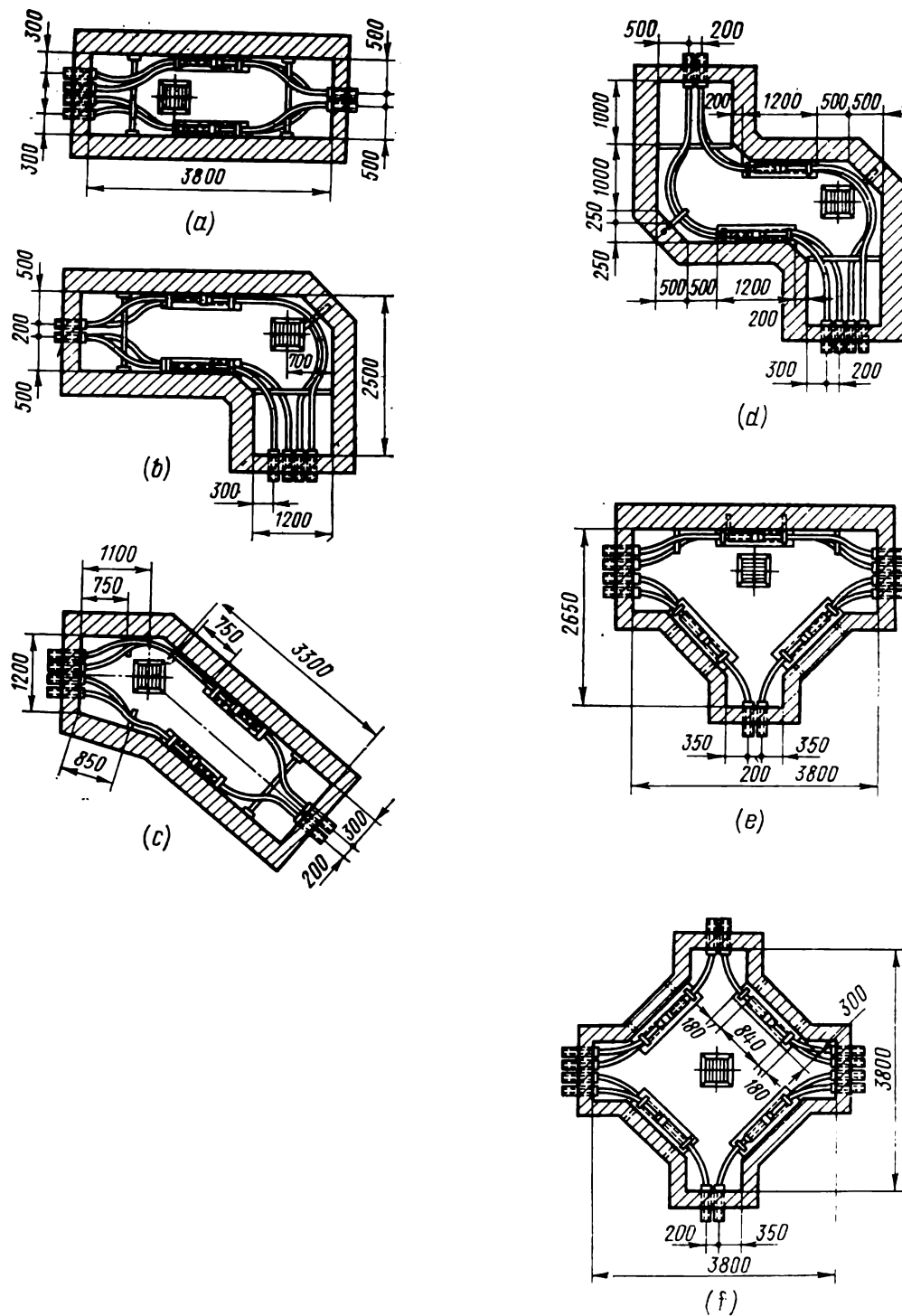


Fig. 77. Constructions of cable conduit manholes
 a—cool; b—angle; c—obtuse; d—Z-shaped; e—T-shaped; f—cross-shaped

Prior to laying cables, the manholes shall be examined and the pipes placed between them cleaned by means of a test (calibrating) cylinder and a wire broach interconnected through a cable rope with a distance of 600 to 700 mm between them. The loose end of the test cylinder is connected to the pulling rope of a winch and then the winch drum is rotated to pull the cylinder and the broach* through the pipes. In this way, in addition to cleaning, the clear opening of the pipes

Table 28

**Maximum Permissible Lengths of Cables and Pulling Forces
Applied to Draw Them into Conduits**

Cable type	Conductor sectional area, mm ²	Voltage, kV						Maximum permissible pulling force, kgf
		up to 1		6		10		
		cable length, m	pulling force required, kgf	cable length, m	pulling force required, kgf	cable length, m	pulling force required, kgf	
CFT	3×50	350	600	265	635	225	635	650
	3×70	350	780	310	895	270	900	910
	3×95	300	860	350	1,070	300	1,225	1,230
	3×120	300	1070	300	1,290	300	1,410	1,560
	3×150	250	1080	250	1,345	250	1,390	1,950
	3×185	250	1310	250	1,470	250	1,610	2,400
ACFT	3×95	300	553	300	757	240	750	760
	3×120	300	670	300	890	280	945	960
	3×150	250	665	250	930	250	970	1,200
	3×185	250	797	250	960	250	1,110	1,480

- Notes.** 1. The following is assumed in calculations: maximum permissible pulling force is taken equal to one sixth of cable conductor strength; ultimate strength of copper wire (MM) is 26 kgf/mm²; that of aluminium wire (AT) is 16 kgf/mm²; coefficient of friction is 0.6.
2. To reduce pulling forces required for drawing the cables into conduits, the conduit ducts must be thoroughly cleaned and finished and the cables coated with a lubricant.
3. Maximum permissible lengths of cables to be drawn into conduits and pulling forces required, that are specified in the above table, will be valid for cables connected to the catenary wire by means of a cable clamp that grips the cable conductors.

is calibrated by destroying with the cylinder hard bosses formed at the pipe joints due to penetration of concrete mortar.

The thickest portion of the calibrating cylinder has a diameter of 85, 105, and 125 mm for ducts of 100, 119, and 141 mm in diameter, respectively.

The winch rope can be drawn into the pipe by many methods, the simplest being by means of two wires with hooks at the ends. Wires are pushed into the pipes at two ends simultaneously and coupled when they meet within the pipe. Then the wire is pulled out on one side of the pipe until the hooked joint is brought out.

* In cleaning heavily contaminated ducts at least two or three broaches, dia 105, 125, or 145 mm, are to be connected in series with the cylinder for the duct inner diameter of 100, 119 or 141 mm, respectively.

Then the pulling winch rope is attached to one end of the wire left in the pipe and the calibrating cylinder and one or more broaches to the other end. A steel rope at least 12 mm in diameter is attached to the last broach to be used for pulling the cable.

To draw a cable in a conduit, it is attached to the rope with a sleeve applied to the cable sheath or with a clamp. The cable drum is placed at the manhole. Prior to drawing in the cable, a detachable steel box with a bellmouth is fitted on the pipe of the conduit and a trough made of a pipe length or a steel sheet is placed at the edge of the manhole chimney. The box functions to protect the cable and the butt end of the pipe against damage in driving the cable into the conduit. The trough prevents excessive bends of the cable while it is being drawn into the conduit.

The cable is to be drawn into the conduit at a speed of not over 5 km per hour uninterruptedly to avoid heavy forces from acting on the cable as it is pulled off. Prior to drawing the cable into the pipe, it is good practice to coat it with consistent grease or grease YC in the amount of 8 to 10 g per metre of cable length.

After the cable is drawn into the conduit, it is to be cut away from the drum so that a cable length protruding from the conduit is sufficient for its making-off and connection in a sleeve.

If further operations are not expected during the present day, the cable leads in the manhole and on the cable drum are to be closed with lead or polyethylene sealing caps. To ensure reliable sealing of the cable, the underside of the polyethylene cap is to be coated with adhesive БФ or БМК, whereupon the caps are fitted on the cable end and secured on the cable sheath with a wire band.

Main disadvantages of laying cables in conduits are as follows:

- (a) high cost of the construction and maintenance of all the conduit elements;
- (b) necessity of replacement of a faulty cable running between two manholes;
- (c) impossibility of utilizing the conductors of appropriate sectional area to afford the desired current density due to poor cooling conditions.

6.3.2. Laying Cables on Supporting Structures and in Troughs

In industrial workshops, over walls of buildings, and in tunnels, cables are laid on supporting structures and on special perforated or welded troughs.

Supporting structures (Fig. 78a) are fabricated from sheet steel, 2.5 mm thick, in the form of racks with a bracket, racks with a clamp, wall-mounted brackets, etc. Racks 2 and plates 6 are provided with openings and the tail ends of brackets 3 and suspension clamps 5 have T-shaped recesses through which the brackets and the clamps are attached to the racks and plates. The brackets have oval holes measuring 20×10 mm to support cables where the cable run changes its direction, for example, as it turns or passes from one horizontal plane to another.

The racks and the wall-mounted plates are fixed to concrete and brick building components with clips or with dowels driven in by means of an CMII gun or a ПИЛ piston gun.

Supporting structures illustrated by Fig. 78a are used for laying cables in dry and moist premises. Metal supporting structures are coated with two layers of

moisture-resistant paint to prevent corrosion. In moist locations, use is made of zinc-plated supporting structures or those composed of zinc-plated parts. Figure 78b illustrates cable laying on supporting structures.

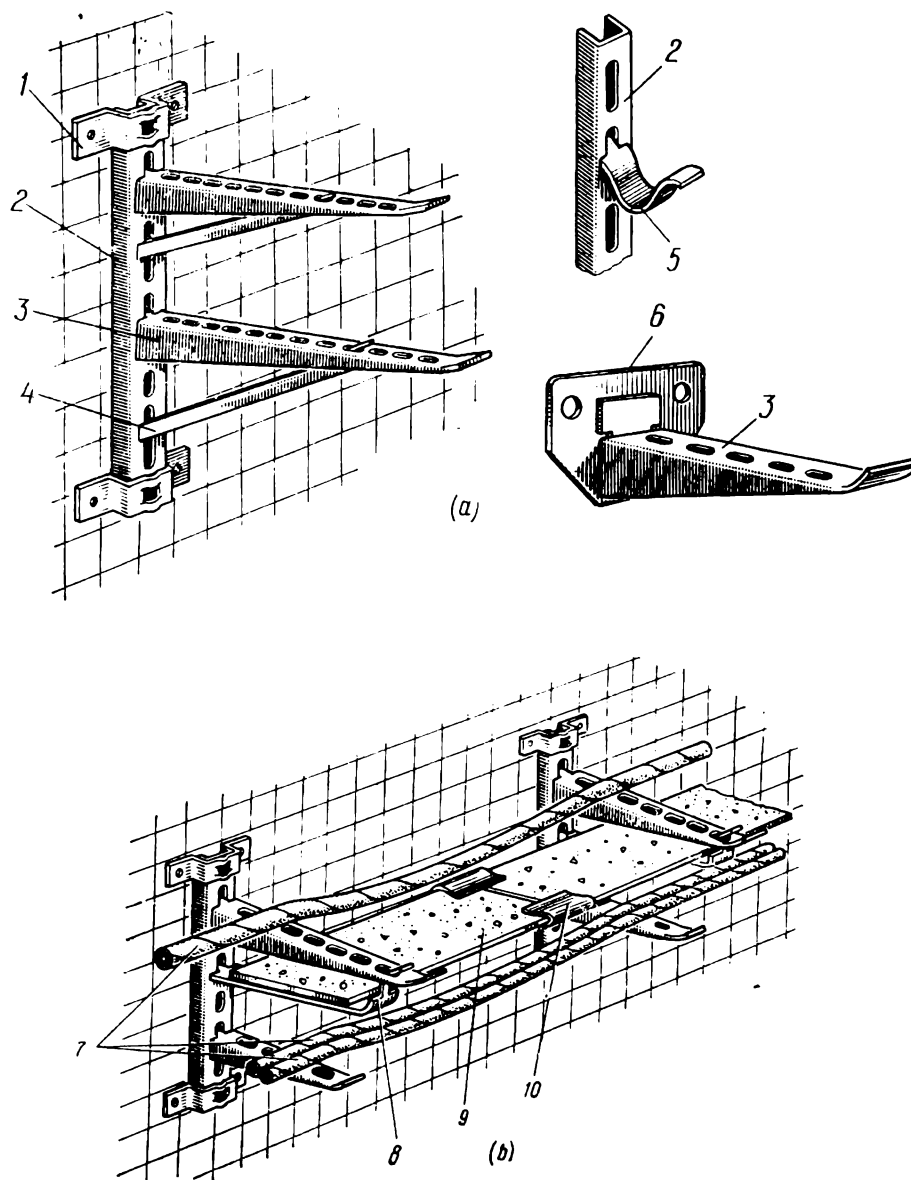


Fig. 78. Supporting structures (a) and examples of cable laying on supporting structures (b)
 1—clip for the attachment of the rack-and-bracket assembly to a wall; 2—rack; 3—bracket; 4—brace; 5—cable clamp; 6—plate; 7—cables; 8—insulating barrier fixing clamp; 9—insulating barrier; 10—clips for joining and fixing the insulating barrier

In dry locations wires and nonarmoured cables are supported by troughs. These troughs are mounted at a height of at least 2 m from the floor on brick and concrete walls of industrial premises, machine halls, and the like locations. Figure 79 a through f shows different methods of installation of troughs with cables laid on them.

The troughs shall be earthed at least in two most distant points. Besides, each branch troughing is earthed at the end. The troughs are joined together so as to form a continuous electric circuit.

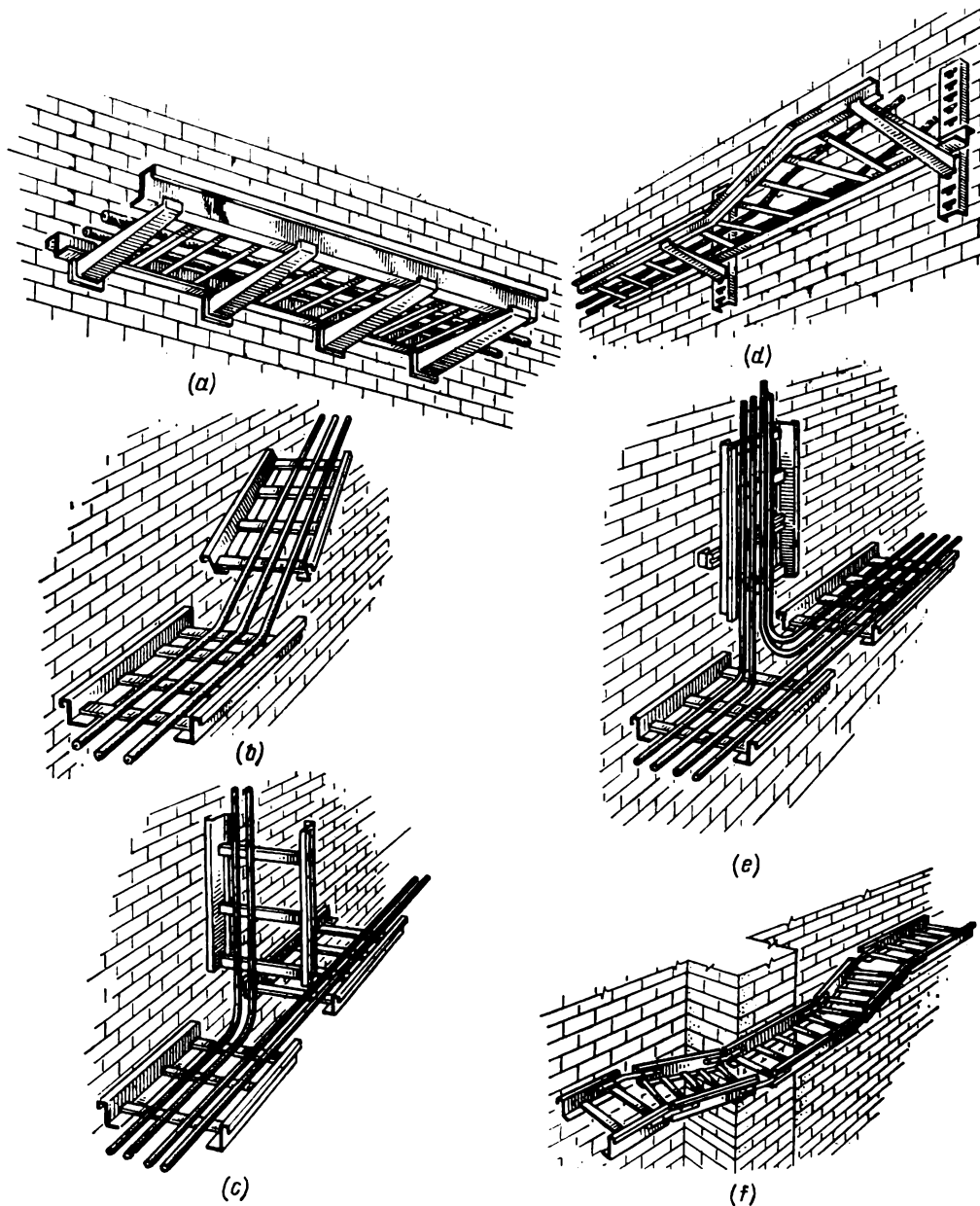


Fig. 79. Arrangement of cable troughs

a—horizontal; b—with cable route passing from one horizontal plane to another; c—branching off upwards on edge; d—passing to a trough of a smaller size; e—branching off upwards flat; f—bypassing a protruding column

All the power circuits of one power unit or all the power and control circuits of several machines, panels, boards, etc. associated with a technological process can be laid in a single trough without separating barriers, but a clearance of 20 mm must be provided between them.

Cables of power, lighting, and control circuits may be laid in the same troughs with wires and cables of other circuits (signalling, remote-control, timing, and the like) only if each of these circuits is isolated with steel barriers or separating casings.

Power cables for 6 and 10 kV service shall be placed in troughs in a single row only and spaced 35 mm apart. Cables are to be interconnected in sleeves installed on special troughs. Cables must be rigidly fixed on straight portions of the line every 0.5 m when arranged vertically, and every 3 m when arranged horizontally. They must be also fixed at all corners and at points of connection.

6.4. Jointing and Splicing Cables in Cast-Iron Sleeves

Special cable sleeves are used for the connection of cable conductors when the length of a cable line is greater than the completed length of the cable. Not more than six sleeves may be admitted on a cable line of 1 km. Cable joints in sleeves must be hermetically sealed, moisture-resistant, mechanically and electrically strong, and corrosion-resistant.

Cable sleeves are classified according to voltage classes (for up to 1, 6, 10, or 35 kV service), application (jointing, splice, or terminal), size (normal or small size), material (Ч — cast-iron, С — lead, Э — epoxy), design form (Оy — Y-shaped, От — T-shaped, Ок — cross-shaped), outdoor or indoor installation, number of phases (terminal three-phase or four-phase), and other characteristics.

6.4.1. General Information

Cast-iron sleeves shall be used for the connection and splicing of three- and four conductor cables of up to 1 kV service.

For the connection of cables use is made of normal-size sleeves, type ЧО (Fig. 80a) and small-size sleeves, type ЧМ (Fig. 80b), the latter being used for plastic-covered cables.

Cable splicing is made by means of splice sleeves, type О (Fig. 81), of the following design forms: От (T-shaped, Fig. 81a), Оy (Y-shaped, Fig. 81b), Ок (cross-shaped, Fig. 81c).

Basic characteristics of jointing and splice sleeves are given in Table 29.

6.4.2. Cable Making-Off

Cables to be joined together shall be made off at the ends. Cable making-off includes sequence stages of stripping the cable ends of protective sheathing and insulation. This operation is part of the cable sleeve installation work.

Make-off dimensions (Fig. 82a) depend on the sleeve design, voltage of cables being joined, and cross-sectional area of their conductors (Table 30).

Cable make-off dimensions can be measured by special straightedges. The type ЖК cable straightedges are available of two varieties, viz., ЖК-1 for up to 1-kV cables and ЖК-2 for 6- and 10-kV cables.

The face side of the ЖК-1 straightedge is calibrated in terms of make-off dimensions for up to 1-kV cables joined in cast-iron sleeves, and its back side in terms of

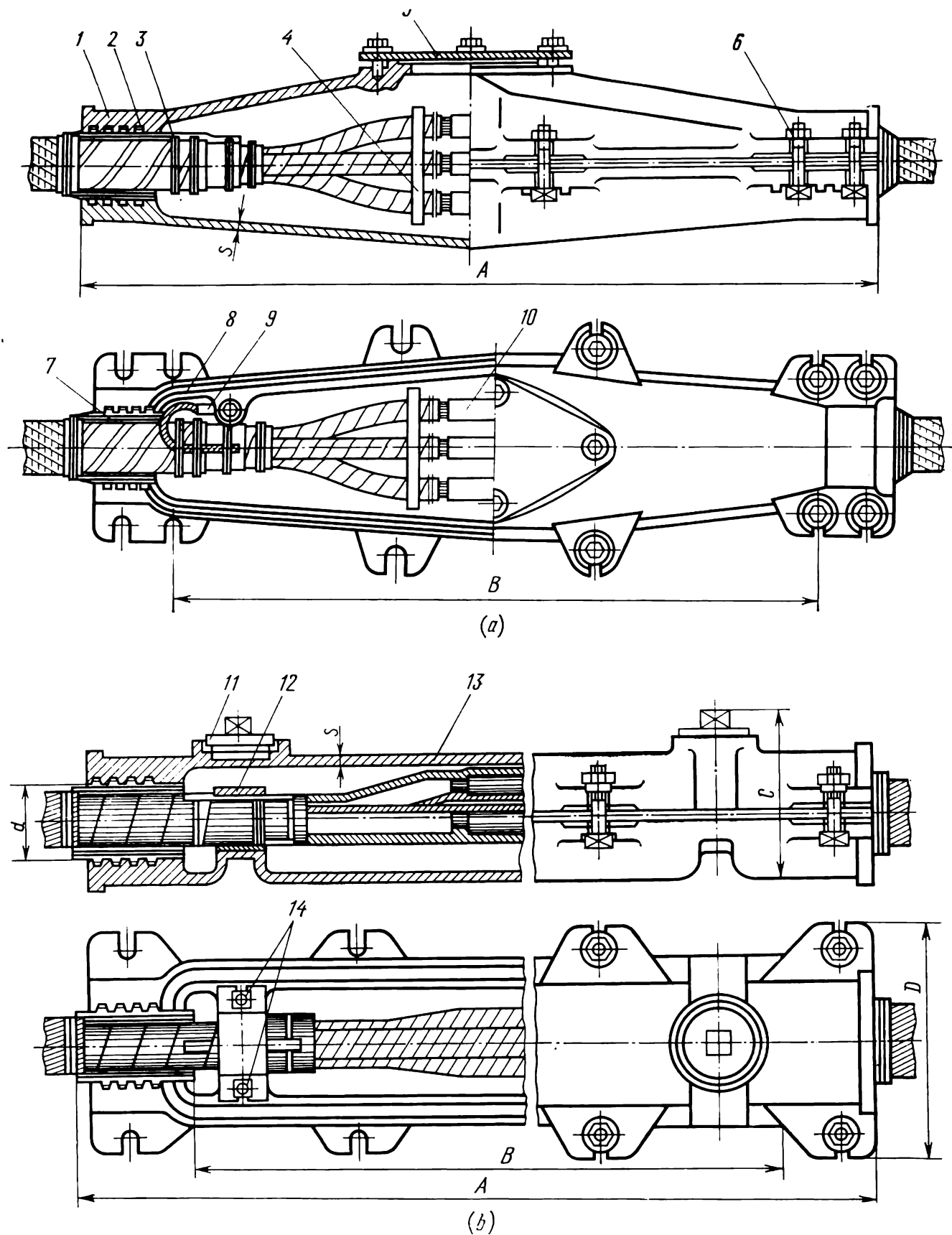


Fig. 80. Cast-iron jointing sleeves for up to 1-kV cables

a—type CЧo; *b*—type CЧм; 1—upper half of sleeve; 2—labyrinth seal; 3—cable; 4—porcelain spacer; 5—sleeve filler hole lid; 6—clamping bolts; 7—wrapping; 8—sealing gasket in the slot of the sleeve bottom half; 9—earthing conductor; 10—jointing sleeve; 11—filler hole plug; 12—clip; 13—wrapping applied by paper roller; 14—clip fastening bolts

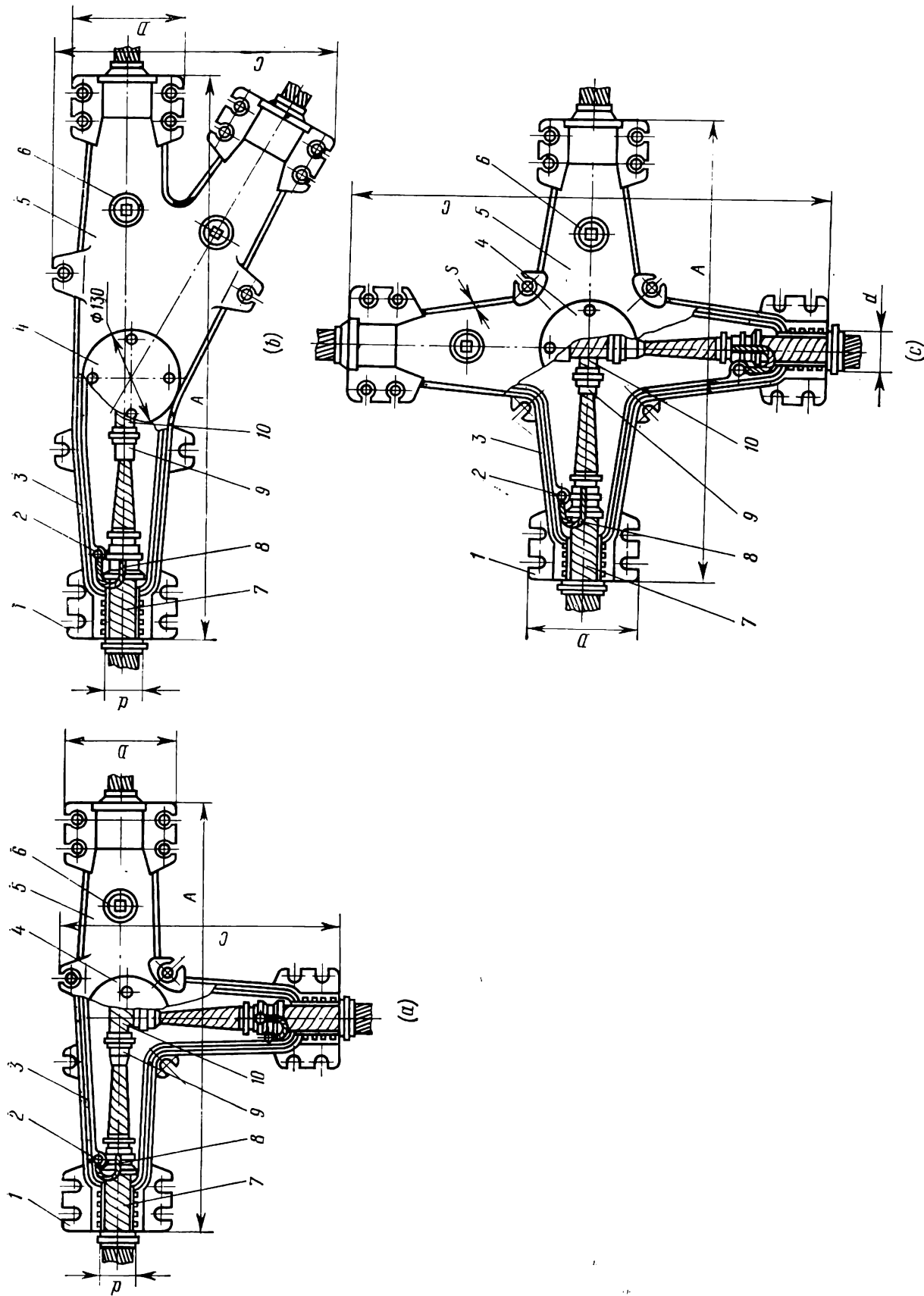


Fig. 84. Cast-iron splice sleeves for up to 1-kV cables

a—type Or (T-shaped); b—Oy (Y-shaped); c—Ok (cross-shaped); 1—sleeve bottom half; 2—earthing bolt; 3—sealing gasket; 4—filler hole cover; 5—sleeve upper half; 6—threaded plug; 7—tarred tape wrapping; 8—earthing conductor; 9—distance paper roller; 10—paper tape wrapping

Table 29

Basic Characteristics of Jointing and Splice Cast-Iron Sleeves

Design form	Conductor sectional area, mm ²		Dimensions, mm						Casting mass per sleeve, kg
	three-conductor cable	four-conductor cable	A	B	C	D	d	S	
Jointing sleeves (Fig. 80)									
СЧo-40	Up to 35	Up to 16	580	460	153	170	40	5	8.7
СЧo-50	50-95	25-70	720	580	185	210	50	5	19.6
СЧo-60	120-185	95-150	830	650	208	240	60	6	31.2
СЧo-70	240	185	900	710	235	260	70	6	37.7
Splice sleeves (Fig. 81)									
СЧм-40	Up to 35	Up to 16	475	375	106	134	40	4	4.8
СЧм-50	50-95	25-70	560	440	117	149	50	5	10.9
СЧм-60	120-150	95-150	630	500	130	174	60	5	16.4
СЧм-70	185-240	185	700	570	138	182	70	5	19.8
Jointing sleeves (Fig. 82)									
ОТ-40	Up to 35	Up to 16	670	159	400	130	40	5	15.2
ОТ-50	50-95	25-70	760	168	450	154	50	6	21.8
ОТ-60	120-185	95-150	900	198	530	180	60	6	31.4
ОТ-70	240	185	1,010	225	605	200	70	7	42.8
Splice sleeves (Fig. 83)									
Оу-40	Up to 35	Up to 16	715	159	310	130	40	5	21.2
Оу-50	50-95	25-70	805	168	345	154	50	6	24.6
Оу-60	120-185	95-150	950	198	420	180	60	6	35.5
Оу-70	240	185	1,100	225	480	200	70	7	40.3
Jointing sleeves (Fig. 84)									
ОК-40	Up to 35	Up to 16	670	159	670	130	40	5	26.9
ОК-50	50-95	25-70	760	168	760	154	50	6	40.8
ОК-60	120-185	95-150	900	198	900	180	60	6	44.5
ОК-70	240	185	1,010	225	1,010	200	70	7	56.7

Note. Dimension B for splice sleeves is the sleeve height (not shown on Fig. 81).

those for cables joined in epoxy sleeves. The JK-2 straightedge is calibrated, respectively, for up to 10-kV cables joined in lead sleeves and for 6- and 10-kV cables joined in epoxy sleeves.

The straightedge is divided into nine vertical lines, two of which characterize the voltage and conductor sectional area of cables, the third line shows the sleeve size, the fourth and the fifth lines indicate the stripped portion of the cable armour and sheath, the sixth and the seventh lines show the dimensions of the circular band and the band of the shielded portion of band insulation, the eighth and the ninth lines show the size of insulation and that of the stripped portions of cable conductors.

Table 30

**Make-Off Dimensions for a 1-kV Cable End to Be Joined or Spliced
in a Cast-Iron Sleeve**

Sleeve design form	Dimensions, mm					
	A	B	C	G	N	O
СЧо-40	295	125	170	115	35	20
СЧо-50	365	135	230	175	35	20
СЧо-60	420	155	265	210	35	20
СЧо-70	455	160	295	240	35	20
СЧм-40	245	105	140	100	25	15
СЧм-50	290	120	170	130	25	15
СЧм-60	310	130	180	140	25	15
СЧм-70	355	130	225	185	25	15
ОТ-40, ОК-40	350	125	225	170	35	20
ОТ-50, ОК-50	395	135	260	205	35	20
ОТ-60, ОК-60	460	155	305	250	35	20
ОТ-70, ОК-70	525	160	365	310	35	20
Оу-40	350/395	125	225/270	170/215	35	20
Оу-50	395/440	135	260/305	205/250	35	20
Оу-60	460/520	155	305/365	250/310	35	20
Оу-70	525/615	160	365/495	310/440	35	20

Notes. 1. For Y-shaped branch sleeves of the Оу type make-off dimensions of the main cable for the left-hand portion of the sleeve are given in the numerator and those for the right-hand portion of the sleeve and for the cable being branched off, in the denominator.
2. Dimension *D* is to be determined on site.

The ЖК-1 and ЖК-2 straightedge can be used to prepare cables for the connection in sleeves and for their termination with a steel or an epoxy bell-shaped box.

Prior to making-off, the cable end is to be dressed and a zinc-plated steel wire band of two or three turns (Fig. 82*b*) is to be applied over the jute serving at distance *A* from the end (Fig. 82*a* and Table 30). The jute serving is unwrapped from the cable end up to the band (Fig. 82*c*) and not removed for it will be further used for the protection of the cable armour against corrosion (after the sleeve is installed). The unwrapped jute is wound for the time being on the cable portion not to be made off.

Another wire band is applied to the armour at distance *B* (see Fig. 82*a*) from the first band. The length of the section between the first and the second band is 50 to 70 mm. Within this portion, the earth conductor is to be connected to the armour bands. In cast-iron jointing and splice sleeves, terminal boxes, and in special sleeves used for submerged cables, this armour section is employed to seal the sleeve throat. The length of this section must be 100 to 150 mm.

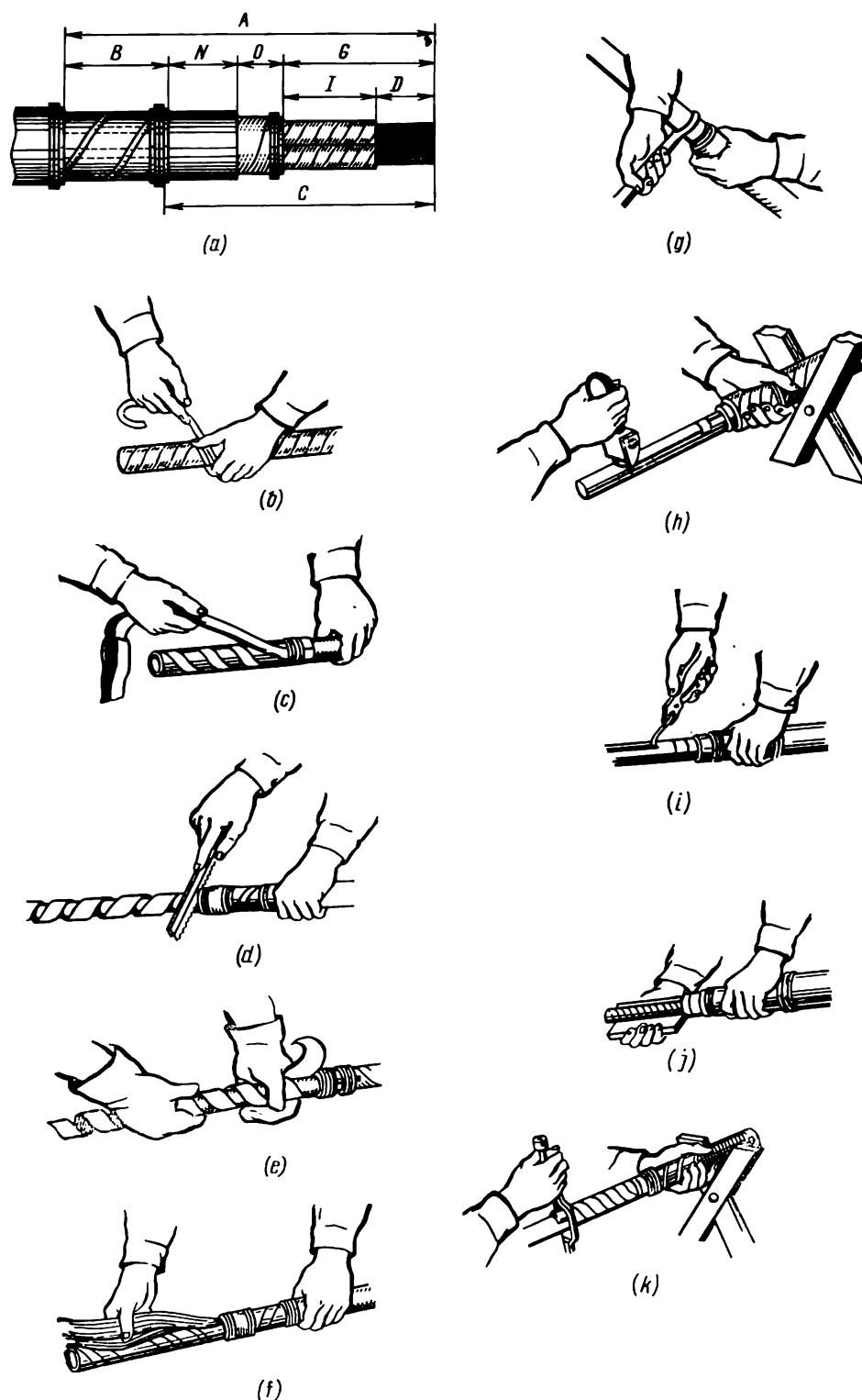


Fig. 82. Cable making-off

a—general view of cable end prepared for jointing or splicing; *b*—placing a band on the jute serving of cable; *c*—unwrapping the jute serving; *d*—cutting the cable armour with an armour cutter; *e*—removing the armour; *f*—removing the cable yarn; *g*—making a circular cut on the cable sheath; *h*—making longitudinal cuts on the cable sheath; *i*—removing the lead sheath strip; *j*—removing the whole sheath from the cable end being made off; *k*—spirally cutting an aluminium sheath by means of HKA knife fitted with a cutting disk

After wire bands are applied to the cable, its armour is to be slightly unwrapped so as to pull it off the sheath, whereupon the edge of the other armour section is to be cut with an armour cutter (Fig. 82*d*) and removed (Fig. 82*e*). Then cable yarn and paper or PVC serving are to be removed from the cable sheath (Fig. 82*f*). In order to remove a sulphate paper serving from the cable sheath, the cable end to be made off is heated to 40 or 50°C with rapid flame of a torch. The cable sheath cleaned of servings is wiped with rags moistened with petrol or transformer oil and heated to 40°C to facilitate the removal of bituminous compound. Then two circular and two longitudinal cuts (Figs. 82*g* and 82*h*, respectively) are made on the cable sheath. The circular cuts shall be spaced 20 mm apart for cables up to 1 kV and 25 mm apart for 6- and 10-kV cables. Longitudinal cuts shall be spaced 10 mm apart. The sheath is cut through half its thickness with special cable knives (HKA, HKC, and the like) furnished with a cutting depth limiter.

The strip that forms between the two longitudinal cuts is gripped with pliers and removed (Fig. 82*i*), whereupon the entire sheath on the cable end is taken off manually (Fig. 82*j*). A knife fitted with cutting disks is used to remove an aluminium sheath, in which case longitudinal cuts are not made. After circular cuts are made, the knife is set at an angle of 45 deg, and the sheath clamped between the V-block and the cutting disk is cut spirally by turning the disk (Fig. 82*k*). The sheath is then removed by means of pliers.

For the final job, the paper band insulation is removed and the semiconducting (black) paper unwrapped, starting from the cable end, and torn away (but not cut with a knife) at distance l (Fig. 82*a*) from the trimmed edge of the lead or aluminium sheath. Fillers between the cable conductors are cut off with a knife, the cutting edge of the knife being set along the conductors towards the cable portion not to be made off.

The circular band above the band insulation stage is removed after the conductors are connected. After the cable ends are made ready for jointing, the cable is prepared for the connection in the sleeve.

6.4.3 Successive Stages in Jointing and Splicing Cable Conductors

For jointing and splicing cable conductors use is made of special tools, fixtures, and accessories briefly listed in Table 31.

Before jointing or splicing cables in cast-iron sleeves, their conductors are dressed manually if their cross-sectional area is up to 25 mm² or by means of a wooden conical template in the case of larger cross-sectional areas. In the case of manual dressing, each conductor is bent separately through the thumb, the cable conductors being held by the other hand near the circular band of the sheath (Fig. 83*a, b*). The size of the wooden template is selected depending on the cross-sectional area of conductors being dressed. The template is inserted between the conductors (Fig. 83*c*) and slowly moved towards the solid cable-portion, with the cable being supported by the other hand just as in the case of manual dressing of conductors.

Upon dressing, the conductors are stripped of their insulation over a length

Table 31

List of Tools, Fixtures, and Accessories for Installation of Cable Sleeves and Terminations

Description	Qty
Medicine chest	1
Metal cans holding 0.5 and 1.5 litres	2
Canister	2
Armour cutter	1
Wax bath	1
Pail holding 10 to 12 litres	1
Funnel for filling the sleeve with compound	1
Mirror for examining sleeves and cables	1
Chisels 25 × 200 and 35 × 400 mm	2
Canister holding 5 litres	1
Pan with lid for heating cable compound	1
Painter's brushes	2
Pliers for removal of rubber and plastic insulation from cable conductors	1
Adjustable wrench No. 3	2
Wrench 3/8 × 1/2 in	1
Fluted-surface rubber mat	1
Cutting pliers	1
Scoop for solder heating	1
Hook with wooden grip	1
Torch or propane burner with bottle and hose	2
Skimming spoon	1
Tool tray	1
Entrenching shovel (picker)	1
Steel crowbar	1
Roof steel tray	1
Mixer for epoxy and cable compounds and for solder	3
Steel 1-metre rule	1
Fitter's hammer, mass 0.6 kg	1
Mallet	1
Set of files (triangular bastard file, 12 in, smooth-cut file, 8 in, round bastard file, 10 in)	3
Electrician's folding knife	1
Simple electrician's knife	1
Knife for the removal of aluminium sheath	1
Knife for the removal of plastic sheath	1
Cable cutting shears	1
Metal cutting saw	1
Beetle for setting lead pipes	1
Screw-driver, 100 mm long	1
Goggles with leather rim	2
Canvas tent with frame	2
Calico-lined polyethylene or rubber (medical) gloves	2 pairs
Canvas mittens or gloves	2 pairs
Forceps	1
Bag for small tools	1
Universal pliers, 200 mm long	1
Implementary support for installation of jointing sleeves	1
Hacksaw blade	6
Tray for scalding compound measuring 520 × 310 mm	1

Table 31 (continued)

Description	Qty
Filling compound and solder heater (electric, gas, or roaster)	1
Flanging tool	1
Steel measuring tape, 10 m long	1
Chests for tools and materials	2
Thermos flask for heating the can with paper rolls	1
Thermometer, scale range up to 300°C, in metal mount	1
Templates for conductor bending	2
Caliper	1
Steel brush	1
Locked metal case	1

Note. Most tools and accessories listed herein are supplied as standard equipment for a cable jointer.

equal to dimension D (see Fig. 82a). At the point where the conductor insulation has been skinned, it is tied with coarse thread to prevent its unwrapping in the course of subsequent operations.

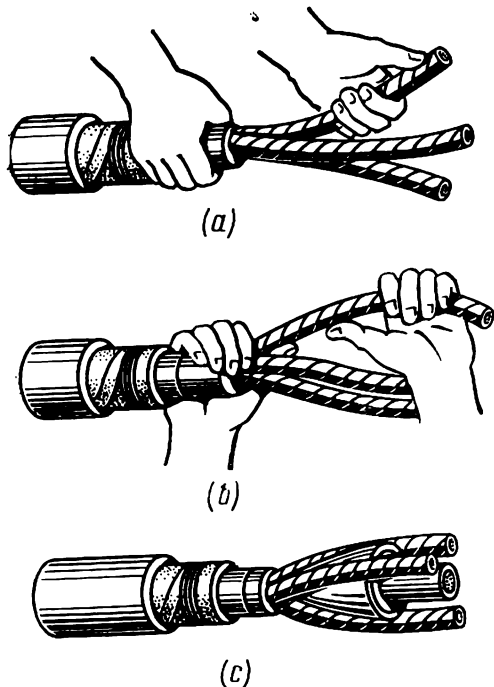


Fig. 83. Successive stages of dressing the conductor ends

a, b —manually; c —by means of a template

Three-conductor and four-conductor cables are joined and spliced by different methods depending on a conductor material and cross-sectional area.

The conductor joints shall be made according to specified technology and must afford a reliable electric contact and mechanical strength.

In selecting a jointing method, due considerations shall be given to characteristic features of each method, material and cross-sectional area of conductors, materials and tools available on site, suitability of this or that method to the design of particular joint or sleeve.

Given below is a brief characteristic of each of the conductor jointing methods specified by Table 32.

Soldering is one of the most popular methods of conductor jointing. Solder thinned by heating penetrates into the metal of conductors being interconnected, cools down and solidifies, thus making a mechanically strong joint. Aluminium conductors are soldered by means of type A, ИО-12, ИА-15, ИМО, И and other sol-

ders. For copper conductors use is made of ИОС-30, ИОС-40, and ИОС-50 solders.

Before soldering aluminium conductors their surfaces must be cleaned of oxide film that impedes the penetration of solder into the conductor metal and does not allow the creation of reliable electric contact.

Soldered joints are made with the use of fluxes, soldering fats and pastes, such as rosin, soldering fat No. 1, No. 5, etc. for copper conductors, and KM-1, AΦ-4A, BAMH, quartz-vaseline, paste for aluminium conductors.

Compression is the best method of connecting aluminium conductors of up to 1 kV. Compression is made with the aid of sleeves and compressing mechanisms (ПК pliers, ПП, ПМП, ПГЭП-2 presses, etc.). By this method, conductors are joined together by indenting sleeves with the aid of a compressing mechanism that

Table 32

Application of Jointing and Splicing Methods for Three- and Four-Conductor Cables of up to 1 kV

Description of method	Cross-sectional areas, mm ²	Recommendations for use
Aluminium-conductor cables		
Jointing by thermit welding with use of type A cartridges	16-240	Preferable
Jointing by compression with sleeves	16-95	Recommended
Jointing by soldering:		
by directly fusing the solder	16-150	Allowable
by pouring the solder	16-240	Recommended
Jointing by gas welding in open moulds	16-240	Allowable
Jointing by resistance butt welding in open moulds	16-240	Allowable
Splicing by gas welding in open moulds	16-240	Preferable
Splicing by soldering with conductors made off in steps:		
directly by fusing the solder	16-95	Allowable
by pouring	16-240	Recommended
Copper-conductor cables		
Jointing by compression in type ГМ sleeves	16-240	Preferable
Jointing by soldering in type ГМ sleeves	4-240	Recommended
Splicing by soldering in type ГОН and ГОП sleeves	16-185	Preferable

Notes. 1. "Preferable" means that the particular method is favoured most. "Recommended" means that the particular method is one of the best. "Allowable" means that the given method is adequate and in some cases used for want of a better technique available.
2. The joints and splices of conductor cables must have a sufficient tensile strength, at least 0.7 that of the cable conductor on a whole section.

exerts pressure above the yielding point of the conductor and sleeve metals, with the result that the sleeves get compressed and indented into the conductors, thereby creating a solid joint. This method is comparatively simple and requires short time, but the material and size of sleeves used must correspond to those of conductors being joined and to pressing mechanisms employed so that the latter could afford sufficient pressure required for indentation.

Gas or electric welding is used for the connection of aluminium conductors having a cross-sectional area of 16 to 240 mm². Gas welding uses the heat of gas (propane-butane, and the like) burnt at 2,300°C and higher. Electric welding utilizes the heat liberated by a high-resistance section of a joint as a welding current

of several hundreds of amperes is passed through it. During gas or electric welding, special shields are used to protect conductor insulation against high heat and also coolers to transfer heat from conductors being welded together.

Thermit welding is one of the most advanced methods of welding aluminium conductors. Thermit welding employs type A cartridges. A thermit cartridge is fired with a special match that affords, while burning, a temperature as high as $1,000^{\circ}\text{C}$ required for the ignition of thermit compound contained in the cartridge. The insulation of conductors welded together in a thermit cartridge shall be protected against high temperature.

6.4.4. Conductor Jointing Methods

Soldering. Aluminium conductors of cables of up to 1 kV are soldered as follows:

(a) by fusing the solder directly in a mould;

(b) by pouring the premelted solder onto the conductors to be joined together.

The (a) method is used for the connection of conductors having a cross-sectional area of up to 150 mm^2 and the (b) method, for those having a cross-sectional area of up to 240 mm^2 .

Aluminium conductors of up to 150 mm^2 area, when soldered together in a mould, are to be connected in a definite sequence. The made-off conductor ends are fanned out (see Fig. 83a) and dressed manually (Fig. 83b) or by means of a wooden template (Fig. 83c) over the apexes of an equilateral triangle. The spacing between cable conductors connected in a cast-iron sleeve C4o depends on the spacing between the centres of porcelain spacers holding the conductors in position. The spacing between conductors joined in a type C4M sleeve depends on the thickness of treated paper-tape insulation applied to the conductor joint after soldering.

Stranded aluminium conductors are to be made off in steps before soldering (Fig. 84a). The number of steps depends on the cross-sectional area of conductors being interconnected, viz., one 10-mm step for conductors of 16 to 35 mm^2 area, two 10-mm steps for those of 50 to 95 mm^2 area, and three 10-mm steps for conductors of 120 to 150 mm^2 area. The central core of the conductor is to be scarfed at an angle of 45° .

Prior to soldering conductors of 16 to 150 mm^2 area in a mould, their stepped end is cleaned of remaining impregnating compound by wiping with a clean rag moistened with petrol. This done, the ends are heated in a torch flame (Fig. 84b) and run over with type A solder. In the process, oxide film is removed with a steel brush 1. The mould 8 (Fig. 84c) is secured on the conductor ends so that the portions to be joined are in the centre, then tied at the ends with a few turns of an asbestos cord 7 to prevent solder leakage in the course of soldering; after that, protective shields 6 are installed.

Soldering is started with heating the conductors and the mould in the torch flame, whereupon a solder A stick 2 (Fig. 84d) is inserted in the flame and melted until the mould is completely filled with it. After the joint has cooled down, the mould is removed together with the wrapping asbestos cord and shields. The soldered portion is filed off to make it round and to remove excess solid solder. The same procedure is used when soldering with the IJO-12 and IJA-15 solders, the

only difference being that the conductor ends to be joined together are not run over with tin.

Aluminium conductors of 16 to 240 mm² area that are joined by pouring molten solder on them are to be made round if they are of a sector shape, scarfed at the ends at an angle of 45 deg, and placed in a steel split mould so that a clearance of 2 mm is provided between the conductors to be joined together. Asbestos cord is to be wound on the mould end and protective shields installed in position, whereupon the conductors and the mould are heated in the torch flame to a temperature

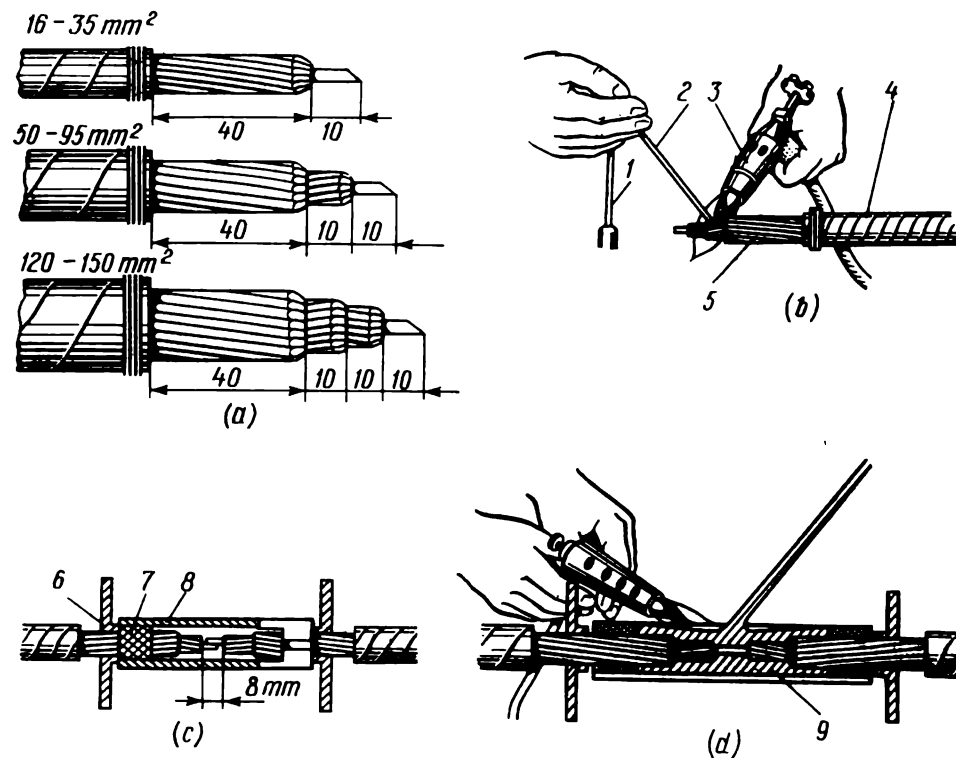


Fig. 84. Successive stages of making off and jointing standard aluminium conductors by directly melting solder in a mould (a, b, c, d)

1—steel bush; 2—solder stick; 3—torch; 4—insulation; 5—conductor; 6—protective shield; 7—asbestos wrapping; 8—mould; 9—molten solder

of 200 to 250°C. Then the desired amount of solder is melted in a cup and poured with a heated skipping spoon in a continuous jet into the mould till it is filled up. In the process, oxide films are removed from the scarfed ends of the conductors by hitting them with a skimming bar.

The cool joint is cleaned of the shields and wrapping, moulds are filed off and the joint scalded with hot compound MII-1 to remove remaining metal particles.

Copper conductors of cables of up to 1 kV having a cross-sectional area of 4 to 240 mm² are soldered by means of the type ГМ copper sleeves provided with a filler hole to introduce solder. Conductors to be joined together are coated with a thin layer of soldering fat and placed in a sleeve so that they meet in the centre of the sleeve and the filler hole is just above the meeting point of the two conductors.

The soldering procedure is the same as for soldering aluminium conductors by pouring the solder.

Aluminium-to-copper joints are soldered by the same methods as for aluminium conductors, the only difference being that the copper conductors are prepared for soldering in the usual way.

Compression. Cable conductors are joined together by compression in sleeves. To this end, the inner surface of the sleeve is cleaned off with a steel broach to

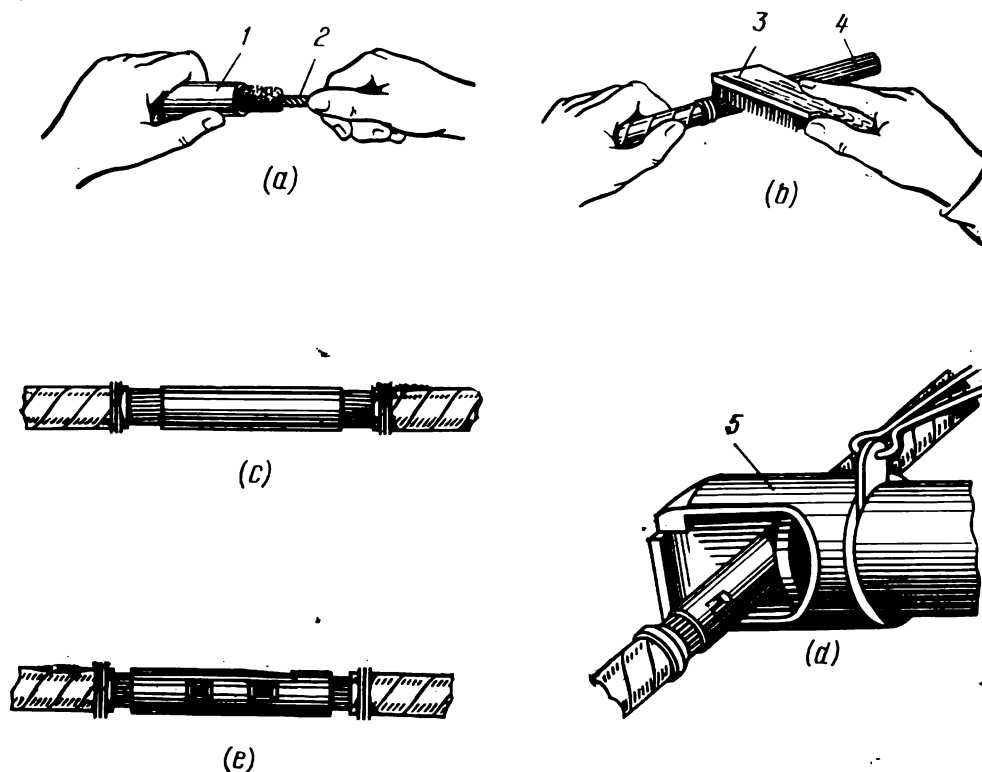


Fig. 85. Jointing cable conductors by compression

a, b, c, d, e—successive stages; 1—sleeve; 2—broach; 3—brush; 4—conductor; 5—press

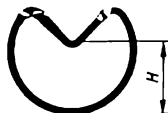
metal lustre (Fig. 85*a*) and coated with quartz-vaseline paste. The surfaces of conductors being joined together are cleaned off with a steel brush (Fig. 85*b*) and wiped with a clean rag moistened with petrol. The conductors are inserted in the sleeve so that their ends are arranged accurately in its centre (Fig. 85*c*). A special compressing unit and a punch with a die (Table 33) are prepared beforehand for the purpose. The joint is fitted between the punch and the die of the compressing unit and the sleeve is indented first at one end and then at the other once or twice depending on the conductor sectional area (Fig. 85*d*).

The quality of the joint obtained is checked (Fig. 85*e*) with a special tool by measuring the remaining thickness at the indented spot (Fig. 86*a, b* and Table 33).

Welding. Aluminium conductors are welded together using the following methods:

Table 33

Selection of Sleeves, Residual Thickness, and Mechanisms for Jointing Aluminium and Copper Cable Conductors of 16 to 240 mm² Cross-Sectional Areas by Compression

Cable conductor design and area, mm ²		Jointing sleeve size				Mechanisms recom- mended for compres- sion of jointing sleeves
				Residual thickness <i>H</i> after sleeve compression, mm		
aluminium	copper	aluminium	copper	aluminium	copper	
16H	16H	ГА-5.4	ГМ-6	4.5	4.5	ГКМ, ПК-1м, РГП-7м
25H	25H, 25c	ГА-7	ГМ-7	6	4.5	
35H	35H, 35c	ГА-8	ГМ-8	7	4.5	
50H	50H, 50c	ГА-9	ГМ-9, ГМ-10	8	6.1; 7	
70H	70H	ГА-11	ГМ-11	9	8.2	РМП-7, РГП-7м, ПГР-20
70c	70c	ГА-12	ГМ-12	9	8.2	
95H	95H	ГА-13	ГМ-13	10	8.2	
95c, 120H	95c, 120H	ГА-14	ГМ-14, ГМ-15	11	9.1	
120c, 150H	120c	ГА-16	ГМ-16	12	9.1	
150c	150H, 150c	ГА-17	ГМ-17	12	10.2	
185H	185H	ГА-18	ГМ-18	13	12.5	ПГЭП-2; ПГР-20
185c	185c	ГА-19	ГМ-19	13	13	
240H	240H	ГА-20	ГМ-20	15	14.4	
240c	240c	ГА-22	ГМ-20	16	14.4	

Notes. 1. In the designation of cross-sectional areas of stranded conductors the following abbreviations are used: H – normal (round) conductor; c – sector conductor.
 2. The designations of compression mechanisms mean the following: ПК-1М – modified large compressing pliers with an interlocking device; ГКМ – hydraulic electrician's pliers; ПМП-7М – manual mechanical press affording a compressing force of 7 tf; РГП-7М – manual hydraulic press affording a compressing force of 7 tf, modernized; ПГЭП-2 – motor-driven hydraulic press.

- (a) thermit pressure welding in a type A cartridge;
- (b) gas welding in an open mould;
- (c) electrical resistance welding in an open mould.

The best joints of aluminium conductors are obtained by thermit welding, and therefore this method is most often mentioned in pertinent instruction manuals.

Gas and electric welding is used only where thermit welding cannot be performed for some reason.

Thermit welding is made in two stages. During the first (preparatory) stage, conductors are made ready for welding. In the course of preparation (Fig. 87) a thermit welding cartridge is selected to suit the conductor sectional area. Each cartridge bears special marking indicating the cross-sectional area of conductors for which it is designed. Cable conductors are welded in the type A cartridge (Fig. 87a). Round cable conductors are cleaned of remaining impregnating compound; sector conductors are also made round. An aluminium sleeve 3 (Fig. 87b)

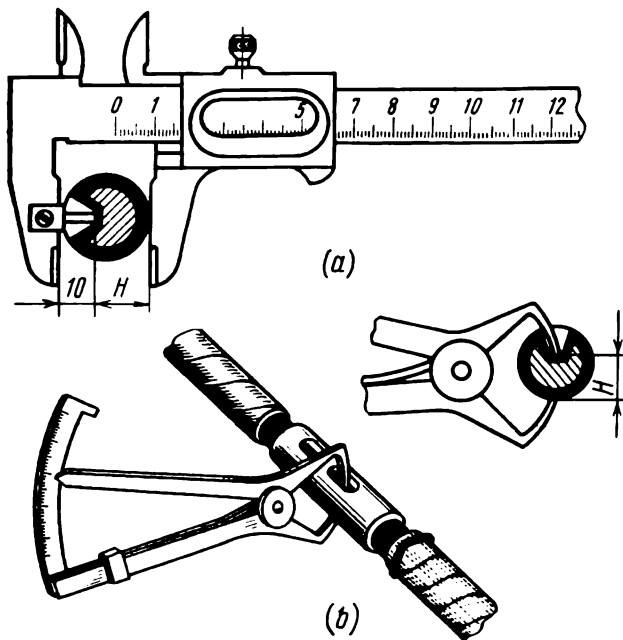


Fig. 86. Tools for measuring remaining thickness after jointing conductors by compression

a—vernier callipers; b—special metering gauge

is fitted on the cable conductor prepared for welding, and then it is inserted in the cartridge (Fig. 87c). To prevent leakage of molten metal, the places where the conductors enter the cartridge are sealed with an asbestos cord 5 (Fig. 87d) using a semicircular-blade steel picker 4. The whole arrangement (Fig. 87e) is mounted on a fixing floor 2 (Fig. 88a) of the fixture 1, chilling pliers 4 are fitted on the conductors, the latter are covered with protective asbestos sheets 5, and thereupon the second stage begins.

Welding in a thermit cartridge is made with the use of the type BAMM flux in a sequence illustrated by Fig. 88b, c, d. After the joint has cooled down, the muffle is chipped off with a chisel (Fig. 88e) and the steel chill is removed from it. After welding the feed head (Fig. 88f) is removed by pliers or by a hack saw.

The joint is filed off till a cylindrical shape is obtained (Fig. 88g) and flushed

in hot scalding compound MII-1 to remove remnants of slag and metal.

Gas or electric welding of conductors is carried out in two stages. First the ends of conductors being joined together are fused into solid rods which are then welded together. Fusion is made in a mould fitted on a vertically placed conductor (Fig. 89a). The mould 1 is first heated in the flame of a burner 3, then the conductor end is fused, whereupon a filler rod 7 is inserted in the burner flame and fused therein to add more molten metal so as to obtain a solid rod at the conductor end.

These rods obtained by fusion at the ends of the conductors (Fig. 89b) are set horizontally, placed in a split steel mould 10 held in position on the conductors by means of wire bands 8 and welded together, at the same time stirring the molten metal 9 with a steel mixer. Electric welding operations are almost the same.

While fusing the conductor ends and carrying out gas welding, the conductor insulation is to be protected with shields 4 and coolers 5; in electric welding, the insulation is to be protected only by coolers that also function as terminals passing the welding current to the conductors.

After the conductors have been joined together, the cable must be earthed.

6.4.5. Cable Earthing

Cables interconnected in cast-iron sleeves are earthed with the aid of two flexible copper conductors of cross-sectional areas corresponding to those of the cable conductors.

Minimum cross-sectional area of earthing conductors, mm ²	Cross-sectional area of cable conductors, mm ²
6	up to 10
10	16, 25, 35
16	50, 70, 95, 120
25	150, 185, 240

The earthing conductor shall be long enough to interconnect the cable sheath and armour with the contact plate of the sleeve.

The earthing conductor is connected to the cable sheath and armour by soldering proceeding as follows. The cable sheath and lead armour are cleaned off with

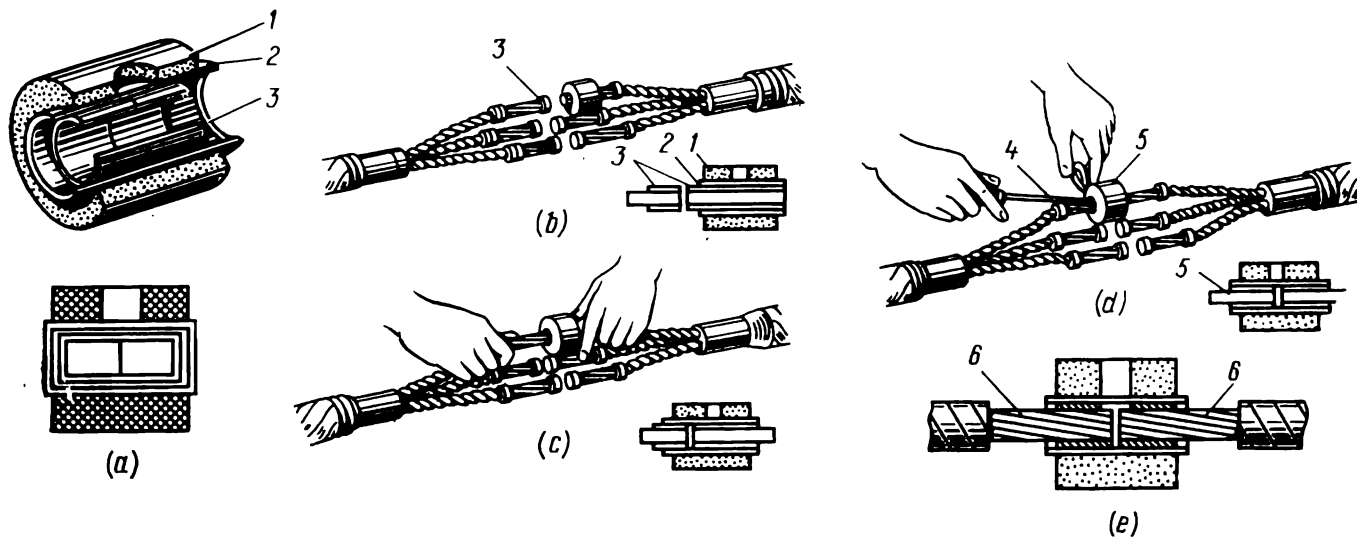


Fig. 87. Preparing aluminium conductors for welding in a thermit cartridge

a—type A thermit cartridge (cutaway view); b, c, d, e—successive stages; 1—thermit muffle; 2—steel chill; 3—aluminium bush; 4—asbestos cord picker with a semicircular blade; 5—asbestos cord; 6—conductors being joined together

a steel brush to metal lustre and run over with solder ПOC-30. The aluminium sheath is run over with solder A. The earthing conductor is flattened on one end and soldered to the sheath and armour of one of the cables. In addition, the conductor is fixed to the cable sheath and armour with two wire bands made of three or four turns of zinc-plated wire, dia 1.2 to 1.5 mm. Where the armour is made of steel bands, the earthing conductor is to be soldered to both the bands. If the armour is made of flat or round wires, the earthing conductor must be soldered to all the wires over the cable circumference. The earthing conductor must never be attached by soldering or by wire bands alone.

The other end of the earthing conductor that is to be connected to the sleeve contact plate shall be terminated with a cable lug by soldering or by compression.

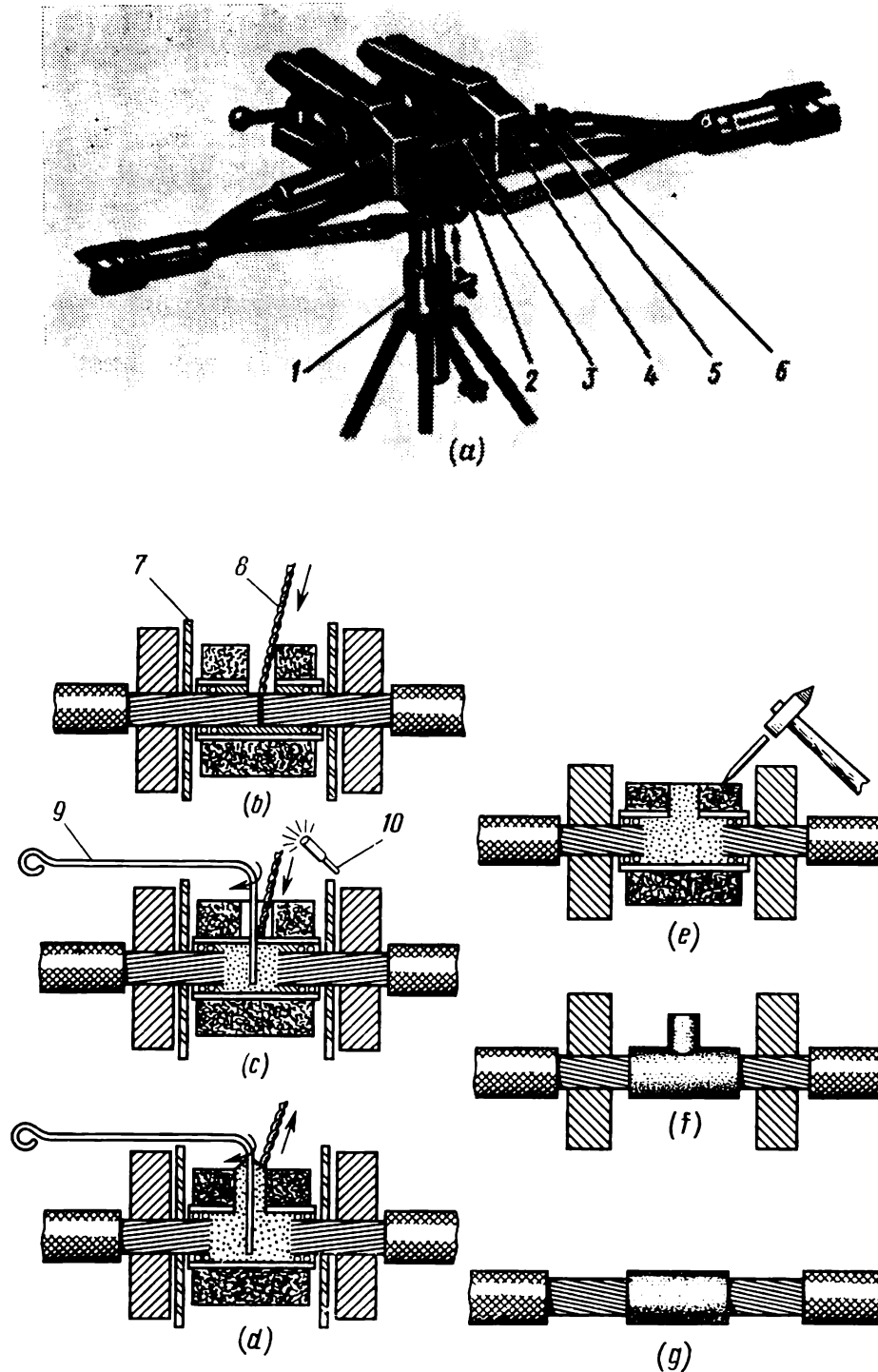


Fig. 88. Jointing aluminium cable conductors by thermit welding

a, b, c, d, e, f, g—successive stages; *1*—fixture; *2*—thermit cartridge fixing floor; *3*—thermit cartridge; *4*—chilling pliers; *5*—asbestos sheets protecting the conductors against flame; *6*—clamp holding asbestos sheets on cable conductors; *7*—shield; *8*—welding rod; *9*—steel wire hook; *10*—match for firing the thermit compound

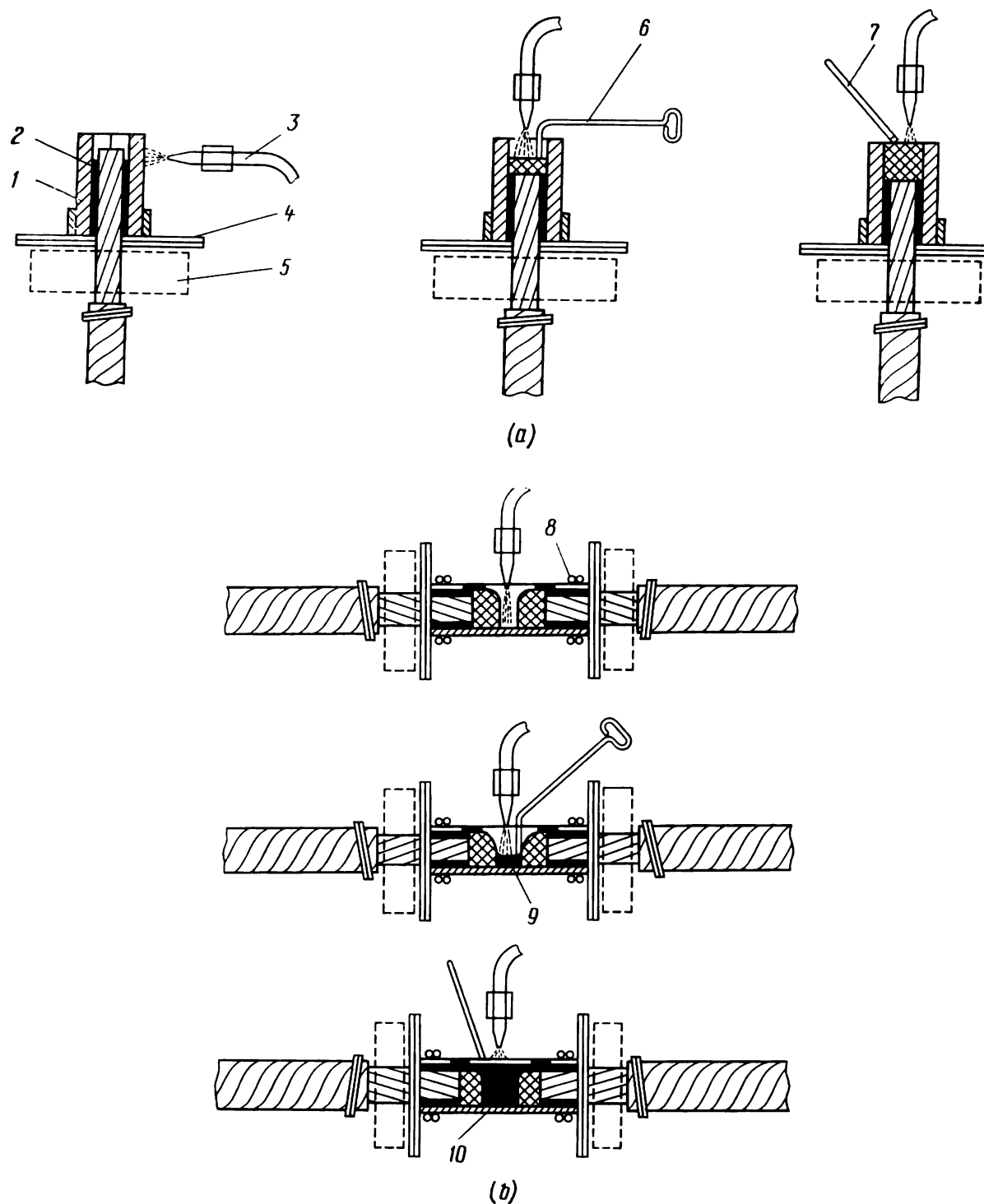


Fig. 89. Jointing aluminium conductors by gas welding

a—fusing the conductor end to obtain a solid rod; b—jointing conductors by welding; 1—mould; 2—asbestos insulation; 3—gas burner; 4—protective shield; 5—cooler; 6—steel hook (mixer); 7—filler rod; 8—wire band; 9—molten metal; 10—split steel mould

A similar procedure shall be used for the earthing conductor to be connected to the other cable.

After the cable conductors are joined together and connected to earthing conductors, jointing sleeves are to be mounted on them.

6.5. Installation of Cast-Iron Jointing Sleeves

Pending its installation on cables, the jointing sleeve must be cleaned of dirt and rust and both its halves must be tried on to the joint.

The lower half of the sleeve is placed under the interconnected conductors, whereupon markings are made on the cable at the points where it will come in contact with the sleeve throats. Then the sleeve bottom half is removed and tarred tape is wrapped in a few layers around the marked-out points on the cable. The wrapping diameter must be slightly greater than the inner bore of the sleeve throats so as to ensure the required tightness of seal at the cable entry into the sleeve.

This done, the bottom half of the sleeve is placed on the joint so as to have the tarred tape wrapping above the sleeve throats, and the earthing conductor lugs are then connected to the contact plates of the sleeve. After that, a packing made of bitumen-treated hemp cord is placed in the slot of the bottom sleeve half and covered with the top half of the sleeve that is to be bolted on site, taking care that the bolts be tightened uniformly to avoid misalignment of the sleeve halves.

For packing, use can also be made of oil-resistant rubber or bitumen-treated jute serving removed from the cable during its making-off.

One of the most responsible operations in mounting the cable sleeves is filling them with cable compound. Improper filling of a sleeve with compound often leads to conductor-to-conductor insulation breakdown at the joint due to accumulation of moisture within the sleeve.

The final operation of filling the cast-iron sleeve with compound is preceded by heating the sleeve and the compound. The sleeve is heated in a gas burner flame to 60 or 70°C, then hot compound МБ-70 or МБ-90 is carried to it in a special pail and poured into the sleeve first one third, then three thirds full, and finally to full volume. The cable compound is then allowed to cool down to 30 or 35°C. In cooling, the cable compound shrinks, therefore it must be topped up.

The cable compound composition is selected depending on local conditions.

After topping up the sleeve, a bitumen-treated cord is inserted into the slot around the perimeter of the filler hole, and the latter is closed with a lid that is screwed in position.

For more reliable sealing of a sleeve laid underground, it is double covered or poured with bitumen compound МБ-70 heated to 130°C.

Cable splicing in cast-iron splice sleeves Oy, Or and Ok is made almost in the same manner as cable jointing. The differences are as follows. Cable conductors are branched off in split or non-split T-shaped sleeves composed of a straight portion to accommodate the conductor of the main cable and a branch portion receiving the conductor of the cable being branched off.

A separate earthing conductor is connected to each of the cables accommodated in the splice sleeve as is the case with cables joined in cast-iron sleeves. Then the earthing conductors of all the cables are bolted together through bolts that join both sleeve halves since splice sleeves are not provided with contact plates.

6.6. Jointing of Cables in Lead Sleeves

Lead sleeves are used for jointing high-voltage cables of 6, 10 kV and higher. These sleeves are made of lead pipes of appropriate diameters during installation.

Lead sleeves bear identification codes in which letters CC mean "junction lead" and numerals 60, 70, 80, 90, 100, and 110 show the diameter of the cable to be joined.

The sleeves are available in six sizes (CC-60, CC-70, CC-80, etc.). The sleeve size also determines the sectional areas of conductors of cables that may be joined in a given sleeve at definite service voltages of cables.

Cable ends are made off for mounting in lead sleeves and cable conductors are connected therein using the same procedures as in the case of cast-iron sleeves.

After these procedures the lead sleeve is installed as follows.

Paper insulation is removed from the cable end by means of a steel string with weights (Fig. 90a) in steps over a length of 16 mm for 6-kV cables or 24 mm for 10-kV cables.

The joint is insulated with treated paper tape unreeled from narrow and wide rolls; 5-mm tape is wound between the sleeve and the steps of factory insulation; 10-mm tape is wound over the sleeve up to the top level of factory insulation, and another six or seven layers over the joints and over the factory insulation (Fig. 90b); 50-mm tape is wrapped over the entire joint. Separately insulated conductors are brought together and wrapped by a common paper band unreeled from a roll 50 or 100 mm wide. The paper band is tied at two points with cotton yarn.

Circular bands of the cable sheath are removed from above the band insulation, whereupon the sheath of each cable is expanded (Fig. 90c) and filed off for the connection to the sleeve and for ensuring a smooth transition of electric field strength from the cable insulation diameter to the sleeve insulation diameter. In making off the conductor insulation, wrapping the conductors in paper band, and expanding the cable sheath, the entire joint is once or twice scalded with cable compound МП-1 heated to 130°C to remove moisture, contaminants and remnants of metal and also to restore the cable impregnating compound layer so as to ensure its normal insulation.

One and then the other end of the pipe are beat off (Fig. 90d) with a wooden beater to make them round so that the ends of the sleeve come in contact with the expanded cable sheaths over the entire circumference.

The sleeve is soldered to the cable sheaths (Fig. 90e), the soldering time being not longer than 2 or 3 min.

Two filler holes are cut in the sleeve (Fig. 90f) in the form of equilateral triangles with 25 to 30 mm sides. The tabs formed in the action are bent out towards the sleeve body.

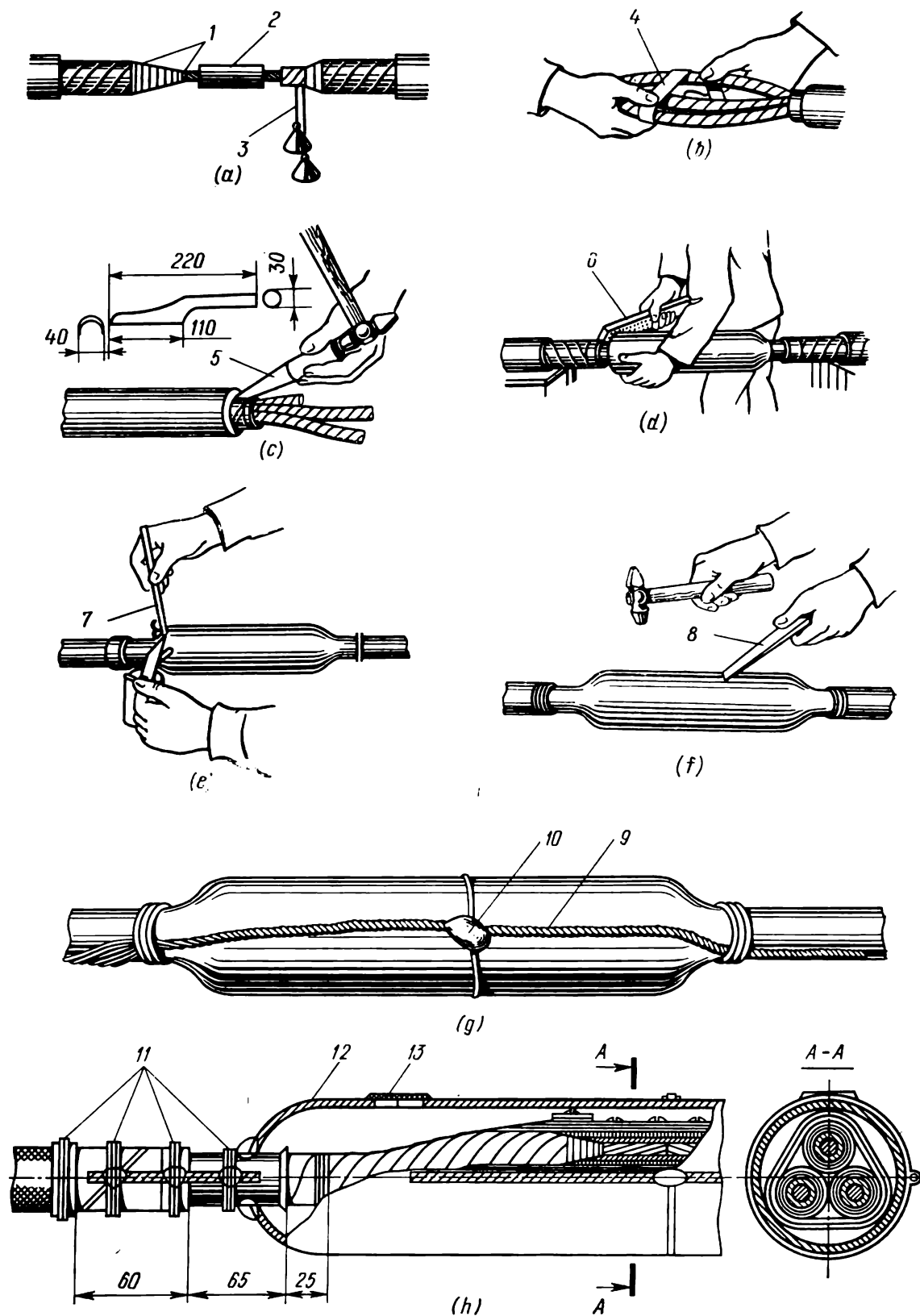


Fig. 90. Installation of jointing lead sleeve for 6-, and 10-kV cables

a, b, c, d, e, f, g, h—successive stages; *1*—steps of factory insulation after making off; *2*—sleeve; *3*—steel string with weights; *4*—paper tape; *5*—expansion; *6*—wooden beater; *7*—soldering stick; *8*—knife; *9*—earthing conductor; *10*—point of earthing conductor connection to the sleeve body; *11*—wire bands; *12*—sleeve body; *13*—filler hole

The sleeve is heated in a running flame of a blowtorch to 40 or 50°C and filled with cable compound MB heated to 170 or 180°C. The cable compound is poured through a funnel inserted in one of the holes until the compound leaking through the other hole is free from air bubbles and foam. As the compound cools down and shrinks, the sleeve is topped up with compound through both the holes. This done, the tabs on the holes are bent back, thus closing the filler holes, and run over with solder.

A fully mounted sleeve is earthed with a flexible copper conductor attached to it by soldering and fixed by wire bands to the sheaths and armours of both the cables and to the sleeve body (Fig. 90g).

A lead sleeve placed underground or in a cable duct is protected against mechanical damage by means of a cast-iron unsealed casing, type КЗЧ or a glass-fiber casing, type КЗС.

Where lead sleeves are buried in earth below the level of the subsoil water, but above the soil freezing level, they are protected with sealed cast-iron casings, type КЗЧГ, filled with special sealing compound.

6.7. Jointing of Cables in Epoxy Sleeves

Epoxy sleeves are widely used for cable joints.

They feature a number of advantages over cast-iron and lead sleeves, viz., they are smaller in size and lighter in mass, take shorter time and lower labour for their installation, readily adhere to metals, provide for reliable hermetic sealing, are not attacked by corrosion, and are sufficiently resistant to moisture.

Epoxy sleeves are manufactured at factories and delivered on site in the form of hollow shells. The shell is mounted on the cable joint and filled with epoxy compound composed of epoxy resin, plasticizer, filler, and hardener.

Plasticizers and fillers raise thermal stability, elasticity, and mechanical strength of epoxy resin and reduce temperature expansion coefficient of the compound to a value approaching that of copper, aluminium, and lead, which are most frequently brought in contact with the compound when cables are joined together. The hardener speeds up polymerization of epoxy resin, thereby reducing the hardening time of the compound.

Epoxy sleeves are most often used for the connection of 1-, 6- and 10-kV cables and for splicing of cables of up to 1 kV.

Epoxy jointing sleeves are designated СЭ, and epoxy branch sleeves ОЭ.

Epoxy jointing sleeves are available in the following design alternates:

СЭн sleeve (Fig. 91a) split crosswise at the centre into two halves; the earthing conductor is arranged outside of the sleeve;

СЭВ sleeve (Fig. 91b) split vertically into two halves; the earthing conductor is arranged within the sleeve in a special slot made in its bottom portion;

СЭм sleeve (Fig. 91c) composed of an epoxy body, a sheet steel screen, and two cones with lead collars soldered to them. One cone is attached to the tubular portion of the sleeve at the factory, and the other on site of installation;

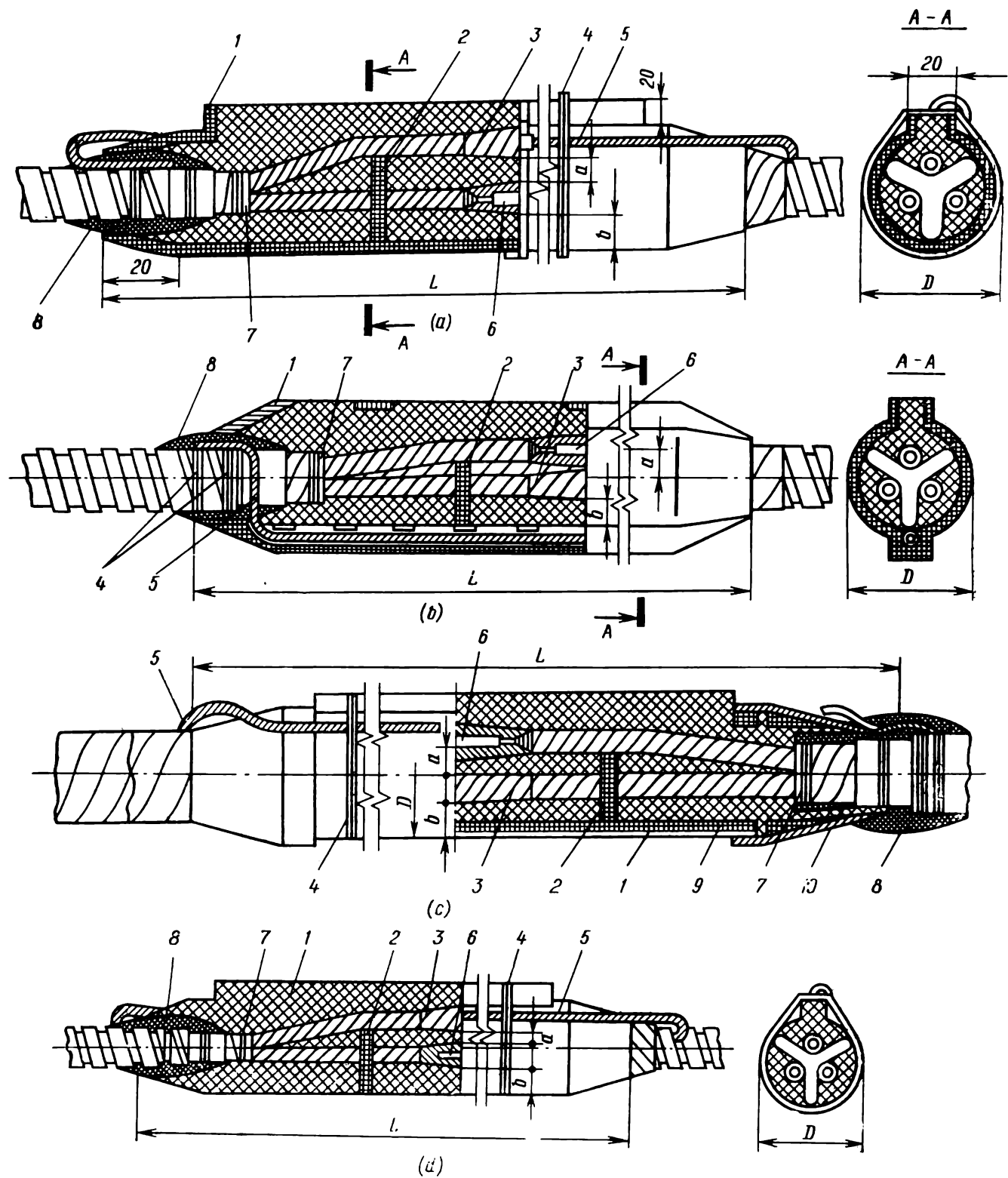


Fig. 91. Epoxy jointing sleeves

a —CЭн; b —CЭн; c —CЭм; d —CЭс; 1—sleeve body; 2—spacer; 3—conductor wrapping; 4—wire band; 5—earthing conductor; 6—connection of conductors; 7—coarse thread band; 8—sealing wrapping; 9—sleeve body shield; 10—lead collar

CЭс sleeve (Fig. 91d) with epoxy body formed on the cable joint after hardening of the compound poured into a removable metal mould mounted on the cable ends to be joined together.

The CЭп, CЭв, and CЭм sleeves are used for 6- and 10-kV cables, and the CЭс sleeves for cables of up to 1 kV (Fig. 91).

For the CЭп sleeve (Fig. 91a) to be installed, fit the sleeve halves on the cable ends to be joined together and move them towards the solid portions of the cable. Before doing this, wrap these cable portions with clean rags so as to prevent dirt from penetration into the interior surfaces of the sleeve. Connect the cable conductors by soldering or welding and make off the cable insulation in steps, just as in the case of lead sleeves.

Then move the sleeve halves back to the portions to be joined and determine the length the earthing conductor should have to bring it out of the sleeve after it is cut into two sections.

Prepare the earthing conductor. For this, strip the ends of a PVC covered conductor or bare one inserted in a PVC tube so that the entire conductor length brought out of the sleeve and 15 mm on either side where it enters the sealing wrapping should not be skinned. The stripped portion of the conductor must be long enough to reliably connect it to the cable armour and sheath by soldering.

Again move the sleeve halves towards the solid portions of the cable and connect the earthing conductor to armour bands and sheath with a wire band 4 made of soft zinc-plated copper wire, then run it over with solder.

Remove coloured tapes from paper insulation and degrease paper insulation by wiping it with a rag moistened with acetone or pure petrol.

Clean off the armour and sheath steps with a steel brush. In the case of an aluminium sheath, clean it under a coat of epoxy compound. Apply to the cleaned-off steps of armour and sheath a sealing wrapping 8 composed of two layers of fiberglass or cotton tape generously slushed in epoxy compound that is applied to each turn. The wrapping tape shall be wound with half the tape width overlapping and shall not reach the edge of the sheath by 5 mm.

Wrap the bare portions of the cable conductors in two layers of fiberglass tape 16 mm wide, half the tape width overlapping, each turn of the tape being generously coated with epoxy compound. In wrapping, fill first the clearance between the point of connection of conductors and the factory insulation. To this end, use fiberglass tape cut lengthwise and put double.

Fit thoroughly degreased epoxy compound spacers 2 on the insulated portions of conductors and secure them on conductors with a band made of dry coarse thread. Shift the sleeve half to the joint and seal it with tarred tape at the cable entrance.

Solder up or connect by compression the earthing conductors brought out of the sleeve throat. Insulate the point of connection of the earthing conductors with a cotton tape coated on the inside with epoxy compound.

Seal the split joint between the sleeve halves with modeling clay to prevent leakage of epoxy compound.

Stretch the earthing conductors loosely along the sleeve body and secure them thereon with wire bands made of soft zinc-plated steel wire.

Fill the sleeve with epoxy compound poured from a low height in a continuous jet, 10 to 15 mm wide. In the action, lightly tap the sleeve with a wooden grip of the hammer to accelerate the escape of gas bubbles to the surface.

Check the compound for its hardness 12 hours after filling the sleeve by touching it with your hand; at a temperature of 20°C the compound must harden in 12 hours after filling. At higher or lower ambient temperatures the hardening time is, respectively, shorter or longer.

Epoxy compound is delivered on site already packed and with the filler introduced. The hardener is introduced at the time of installation of sleeves and terminations. The compound must be thoroughly mixed with the hardener and left to settle 10 to 15 min for the escape of air. The ready compound is effective for a period of:

0.5 to 1 h at an ambient temperature of 0 to 10°C
 1.5 h at an ambient temperature of 11 to 20°C
 2 h at an ambient temperature of 21 to 35°C

In mixing or filling the epoxy compound, care shall be taken to prevent its contact with human skin and to protect human eyes because the compound (while not polymerized) contains toxic chemical agents that may cause local irritation and inflammation.

In mounting the CЭв sleeve (Fig. 91b), solder the earthing conductor 5 to the armour bands and to the sheath of one of the cables being joined together. This done, set one of the sleeve halves on the joint for the time being to make sure that the earthing conductor, which has already been connected to the armour bands and to the sheath of one of the cables, fits well in length the groove provided in the bottom of the sleeve where the conductor will later be placed. This done, remove the sleeve. Solder the earthing conductor to the armour bands and the sheath of the other cable. Apply a sealing wrapping 8 to the armour and sheath steps and to the bare portions of conductors where they are joined together proceeding in the same manner as has been described above for the CЭп sleeves.

Degrease the insulation with acetone and fit degreased spacers 2 at appropriate places. Place one of the sleeve halves on the joint and fit the earthing conductor in the groove in the sleeve bottom. Secure the earthing conductor in position by means of bosses provided for the purpose. In the sleeve sections where there are no bosses, set provisional strips, size 100 × 15 mm, made of 0.4-mm tin.

Then place the other half of the sleeve on the joint and remove the provisional fastening strips.

Join both the halves together with clips. At the bottom also fix them with clamps. Seal the longitudinal seam with modeling clay and then fill the sleeve with epoxy compound proceeding in the same manner as has been described above for the CЭп sleeves.

In mounting the CЭм sleeve (Fig. 91c) fit its tubular portion together with the cone on one end of the cable and the other cone on the other cable end. Join together the conductors of the cables, degrease insulation, apply wrapping tape to the bare conductors at the points of their connection, and place degreased spacers proceeding in the same manner as in the case of CЭп and CЭв sleeves.

Here the wrapping tape is not applied to the armour and sheath steps.

Then join the tubular portion of the sleeve with the other cone, beat off the lead collars with a beater till they come in tight contact with the cable sheath over the entire circumference, and provisionally seal the cable entry into the sleeve with PVC tape.

Attach the insulated earthing conductor to the cable armour bands and sheaths with a wire band, and solder them thereon just as in the case of the CЭП sleeves.

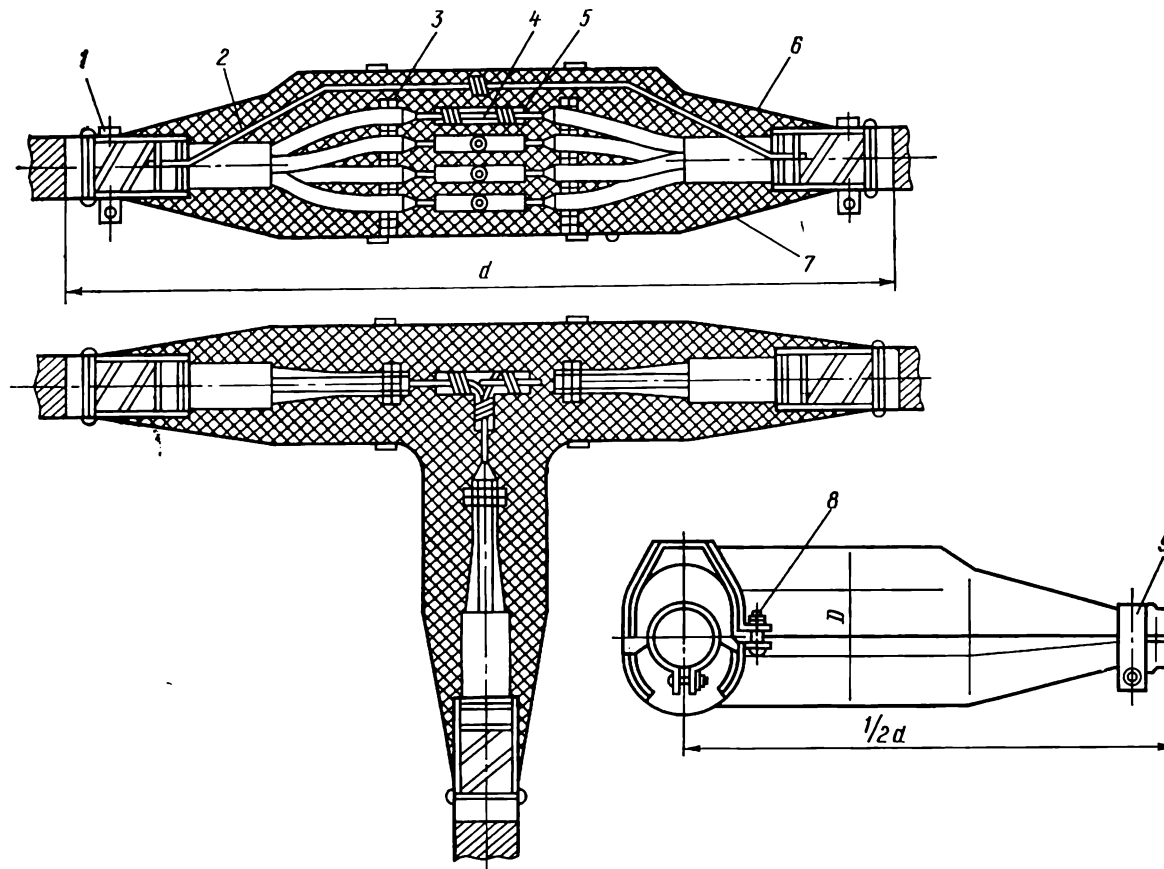


Fig. 92. Type OЭ epoxy splice sleeve for up to 1-kV cables

1—wrapping made of cotton tape covered with epoxy compound; 2—earthing conductor; 3—spacer; 4—splicing of conductors; 5—splice sleeve; 6—mould upper half; 7—mould lower half; 8—clamping bolt; 9—clip

Join the tubular portion of the sleeve to the lead collar of the cone by means of the ПІОС-30 solder at three points equally spaced 120 deg apart over the circumference to ensure electrical connection between them.

Secure the earthing conductor at two points with a wire band and fill the sleeve with epoxy compound.

After the compound has hardened, solder the lead collars to the cable sheaths.

Degrease the bare portions of aluminium cable sheaths and the sleeve collars on a length of 30 or 40 mm with acetone, coat them with epoxy compound and apply epoxy-compound treated wrapping tape in two or three layers, half the tape width overlapping.

In mounting the CЭс sleeve (Fig. 91d) place one half of the removable steel mould on the joint to see that the earthing conductor (already attached and soldered to

the armour and sheath of one of the cables being interconnected) is long enough to be brought out through the sleeve throat. Place the earthing conductor as is shown by the illustration, remove the mould, attach and solder the earthing conductor to the armour and sheath of the other cable.

Prior to placing the mould on the joint, coat its inner surfaces with transformer oil or solid oil so as to facilitate its removal after the compound has hardened.

For the subsequent operations proceed as in the case of the CЭп sleeve.

After the compound has hardened, remove the mould.

For mounting the CЭс sleeve, use can be made of a plastic mould whose inner surface is not coated with oil and which is not removed after the compound has hardened.

Table 34

Basic Dimensions of Jointing and Splice Epoxy Sleeves

Sleeve size	Conductor sectional area (mm ²) for cables rated at voltage, kV				Dimensions, mm			
	up to 1		6	10	L	D	^a (min)	^b (min)
	three-conductor	four-conductor						
Jointing sleeves CЭ (see Fig. 91)								
CЭс-1	Up to 10	—	—	—	330	40	8	10
CЭс-2	16-50	Up to 35	—	—	400	50		
CЭс-3	70-120	50-95	—	—	440	75		
CЭс-4	150-240	120-185	—	—	510	80		
CЭп-5	—	—	10-70	16-50	570	75	10	12
CЭВ-5	—	—			570	85		
CЭМ-5	—	—			510	77		
CЭп-6	—	—	95; 120	70; 95	620	85	10	12
CЭВ-6	—	—			620	95		
CЭМ-6	—	—			560	87		
CЭп-7	—	—	150; 185	120; 150	660	110	10	15
CЭВ-7	—	—			660	110		
CЭМ-7	—	—			600	102		
CЭп-8	—	—	240	185; 240	730	120	10	15
CЭВ-8	—	—			730	120		
CЭМ-8	—	—			670	112		
Splice sleeves ОЭ (see Fig. 92)								
ОЭ-1	Up to 25	Up to 16	—	—	500	56	7	10
ОЭ-2	35-70	25-50	—	—	560	66	8	10
ОЭ-3	95-150	70-120	—	—	620	76	10	12
ОЭ-4	185; 240	150; 185	—	—	750	96	10	15

Epoxy sleeves for cables laid in tunnels, channels, and other cable constructions are protected against mechanical injury by means of protective casings. A casing is essentially a piece of a thick-walled tube, 1,250 mm long and at least 150 mm in inner diameter, with its interior surfaces lined with two layers of asbestos sheets, 4 or 5 mm thick. After the sleeve is placed in the tube, the latter must be closed with end caps made of 20-mm thick asbocement, one of the end caps being screwed in position and the other fitted without any fastenings. The cable sleeve shall be displaced within the casing towards the screwed-in end cap.

In mounting the OЭ sleeve (Fig. 92) the cable ends are made off and the conductors spliced in the same manner as in the case of making off and splicing for the connection in cast-iron sleeves, type CЧo. Epoxy compound is poured on site in a removable hard metal or plastic mould. The detachable mould is mounted and filled with epoxy compound proceeding in the same manner as in the case of cable jointing sleeves CЭ.

Basic mounting dimensions of epoxy sleeves CЭ and OЭ are given in Table 34.

6.8. Termination of Cables

Cable ends are terminated to isolate them from cable conductors connected to the leads of circuit-opening devices, switchgear busbars, and other elements of an electrical installation.

Cables for up to 10-kV service are terminated in bell-shaped boxes, epoxy compound, by means of PVC tapes and rubber insulating branch sleeves.

6.8.1. Cable Termination in Bell-Shaped Boxes

Steel bell-shaped boxes (type КББ) are widely used for the termination of cables of 10 kV electrical installations operating in dry and heated or nonheated premises. Bell-shaped boxes КББ (Fig. 93) are of three modifications, as follows:

КББм-type oval small-sized coverless box mounted without porcelain bushes (Fig. 93a). These boxes are used for the termination of cables of up to 1 kV having a cross-sectional area of 120 mm² (three conductor cables) and 95 mm² (four-conductor cables);

КББК-type round box where the cable conductors are arranged at their exit from the box as if at the apexes of an equilateral triangle and spaced 120 deg apart over the box circumference (Fig. 93b);

КББо-type oval boxes where the cable conductors are arranged at their exit from the box in a single row (Fig. 93c).

The КББо and КББК terminations are used for cables of up to 10 kV irrespective of the conductor sectional areas. For 3, 6, and 10 kV cables, the box is mounted with a cover and porcelain bushings; for cables of up to 1 kV, the cover and the bushings are omitted.

A cable end to be terminated in a steel bell-shaped box is made off almost in the same way as for jointing in a type CЧo cast-iron sleeve. Further successive stages illustrated by Fig. 94 are as follows.

The steel box selected to suit the cable voltage and conductor sectional area is cleaned of dirt, put on the cable and shifted to the solid cable-portion (Fig. 94a) that must be previously wrapped in paper to prevent dirt from getting in the bell.

The made-off cable end is scalded with cable compound МП-1 heated to 130°C. Locating points of porcelain bushings are marked on the conductors and then, at

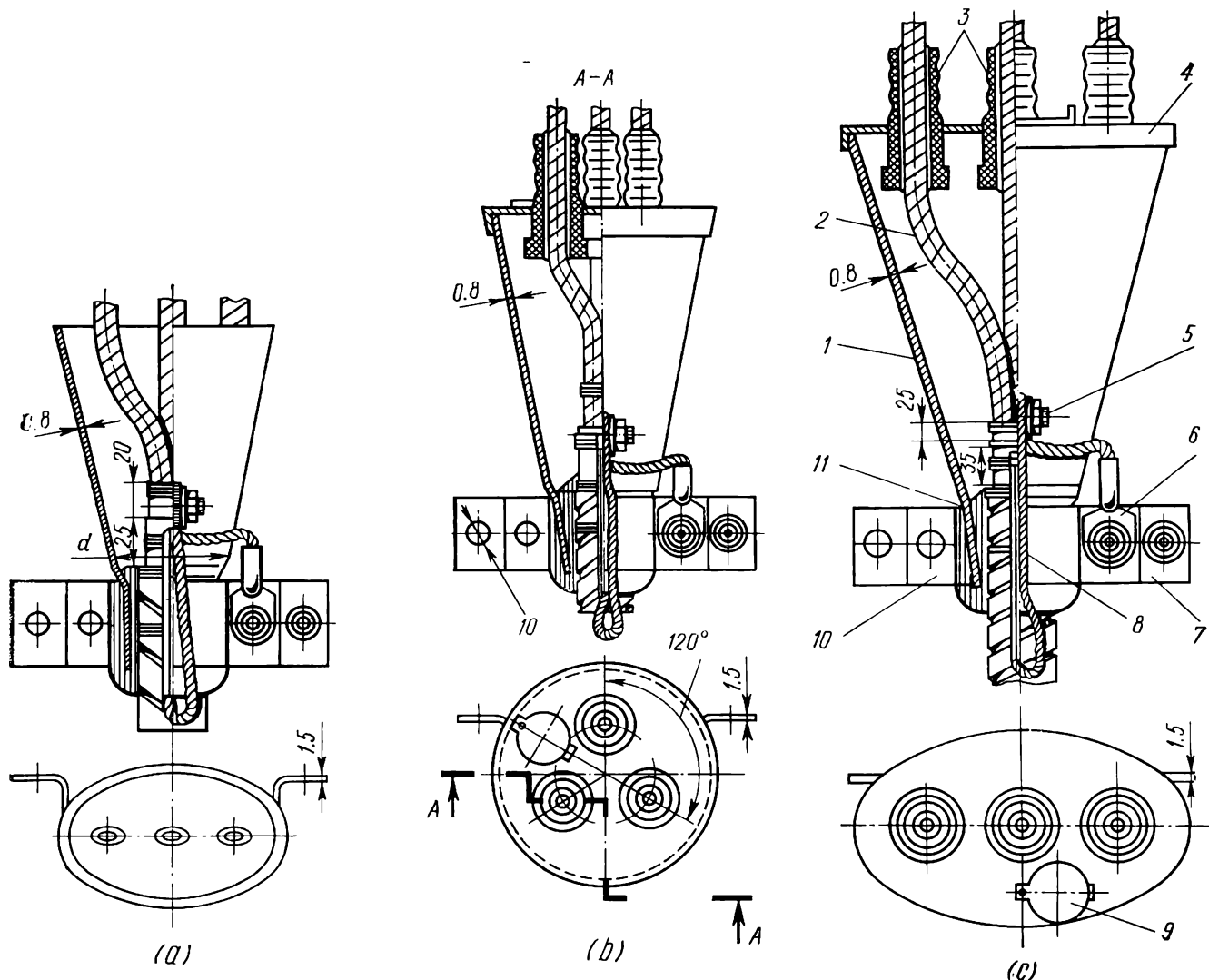


Fig. 93. Cable termination in steel end bells

a—КББм; b—КББк; c—КББо; 1—roof-steel end bell; 2—cable conductor wrapped in adhesive PVC tape; 3—porcelain bushings; 4—end bell cover; 5—bolt M8; 6—lug; 7—lower half-clip; 8—earthing conductor; 9—filler hole lid; 10—upper half-clip; 11—tarred tape wrapping

a distance of 50 mm from these marks towards the root of the make-off, the conductors are wrapped in three or four layers of PVC adhesive tape (Fig. 94b), half the tape width overlapping, up to the bare portions of conductor ends.

The bell is temporarily pulled on its installation place, the conductors are arranged within the bell as is shown by Fig. 94c, the location points of porcelain bushings and of the bell throat determined more accurately, and then the bell is moved back again.

The earthing conductor is secured to the cable sheath (Fig. 94*d*) and armour (Fig. 94*e*) with wire bands and then soldered (Fig. 94*f*). The soldering time must not exceed 2 or 3 min. This done, the circular band of the sheath that has been left on the cable after its making-off is removed.

The portion of the cable armour to receive the bell throat is wrapped in tarred tape applied usually in six to eight layers. The tape is to be wound in a conical

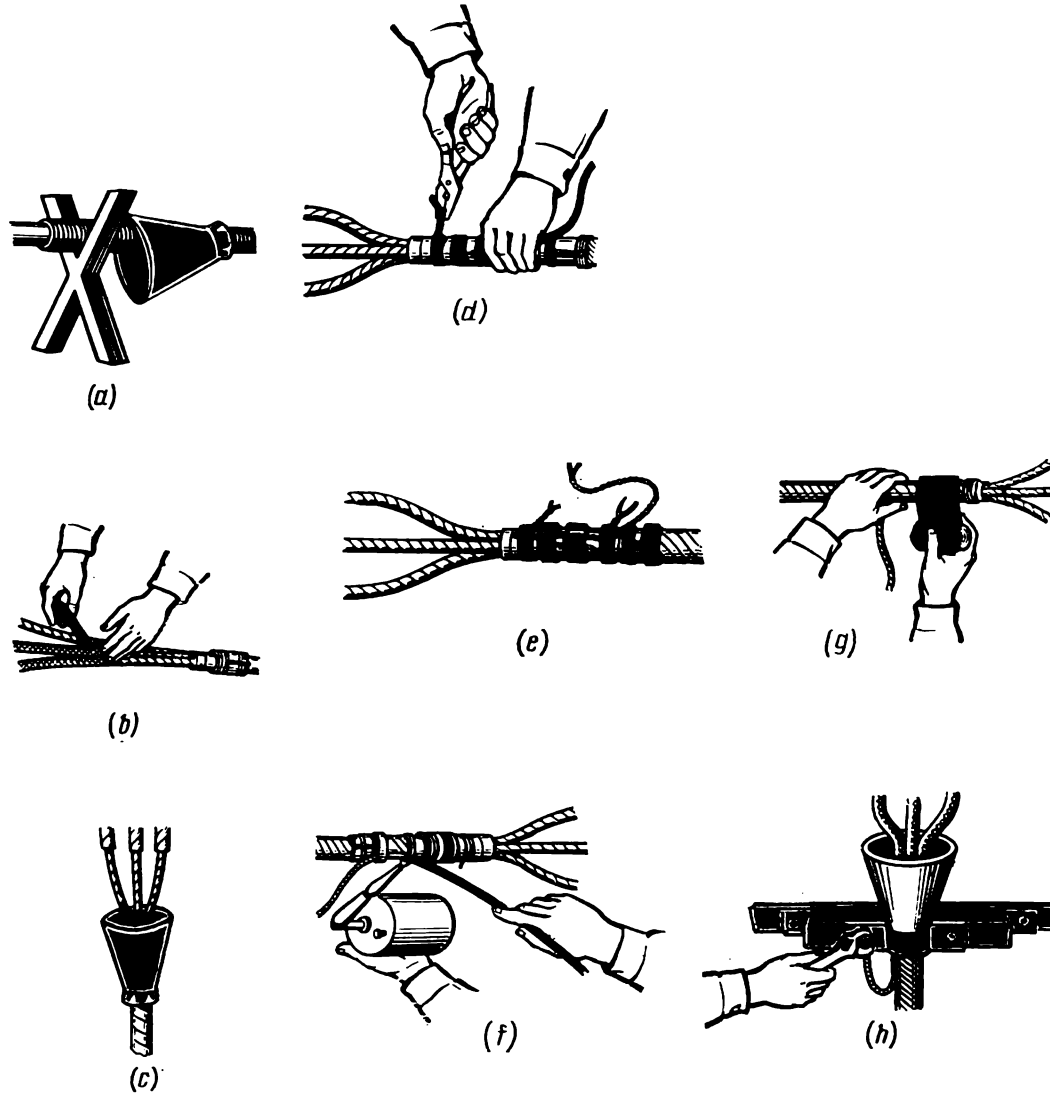


Fig. 94. Installation of KBB end bell

a, b, c, d, e, f, g, h—successive stages

manner so as to ensure a tight fit of the bell on the cable. After three or four layers of the tape are applied, the earthing conductor is laid along the cable, whereupon the remaining layers are wound (94*g*) so as to have the earthing conductor in the middle of the wrapping.

The bell is set on the wrapping, its throat is wrapped in two or three layers of tarred tape, the cable, the bell, and the earthing conductor are secured on a supporting structure (Fig. 94*h*) by means of clips and bolts.

The location points for porcelain bushings marked on the conductors are wrapped in PVC adhesive tape or varnished cloth coated with zapon-glyphthalic varnish in a conical manner and then the bell cover and porcelain bushings are fitted on the conductors.

The cable conductors are dressed to a shape most convenient for their connection to an electrical device and terminated in cable lugs through which they are connected to respective terminals of the device or to the switchgear busbars.

For the final operation, the bell-shaped steel box is filled with bituminous cable compound of a composition suitable for the rated voltage of the cable and for the particular environmental conditions. Just prior to its filling, the box is heated to 50 or 60°C, and the cable compound to 130°C. Hot compound is poured into the box through a filler hole in a continuous jet. As the cable compound cools down and shrinks, the box is topped up so that its final level (after the compound has completely cooled down) is not more than 10 mm below the upper edge of the bell.

The cable box, the clip, and the supporting structure are coated with two layers of enamel paint (No. 270, ПХВ-715, and the like).

6.8.2. Cable Termination in Epoxy Compound Bell

Epoxy terminations are easy to make, provide for reliable sealing and high chemical resistance, and also for high electric and mechanical strength, which makes it possible to dispense with porcelain bushings and a protective metal casing. Moreover, they are fire- and heat-resistant; their working temperatures range from minus 50 to plus 90°C.

The type designation of these terminations is КВЭ. They are used to terminate cables for up to 10 kV service routed indoors in all types of locations and outdoors. In the latter case, provision shall be made to protect them against direct precipitation and sun rays.

The epoxy termination is formed after epoxy compound poured in a detachable mould fitted on the cable end has solidified. This termination is of a bell shape.

The type КВЭ bell-shaped epoxy terminations (Fig. 95) may be of the following design alternates:

КВЭН termination (Fig. 95a) using Najrit rubber tubes fitted on cable conductors; suitable for use in dry indoor locations;

КВЭД termination (Fig. 95b) with double-layer tubes on cable conductors (PVC inner layer and polythene outer layer); suitable for use in humid locations, in tropics and subtropics;

КВЭП termination (Fig. 95c) with insulated leads soldered within the termination to cable conductors and brought out; suitable for use under the same conditions as the КВЭД terminations, but employed only for cables with stranded conductors of up to 1 kV service;

КВЭз termination (Fig. 95d) with Najrit tubes on single (nonstranded) conductors and with retainers inside the epoxy bell; suitable for use under the same conditions as the КВЭД terminations, but only for cables with single conductors for up to 1 kV service.

There are also КВЭо terminations made of cotton tapes that are bonded together by epoxy compound. These terminations are made on single-conductor cables for up to 1 kV service, the operating conditions they are designed for being the same as those for the КВЭН and КВЭД terminations.

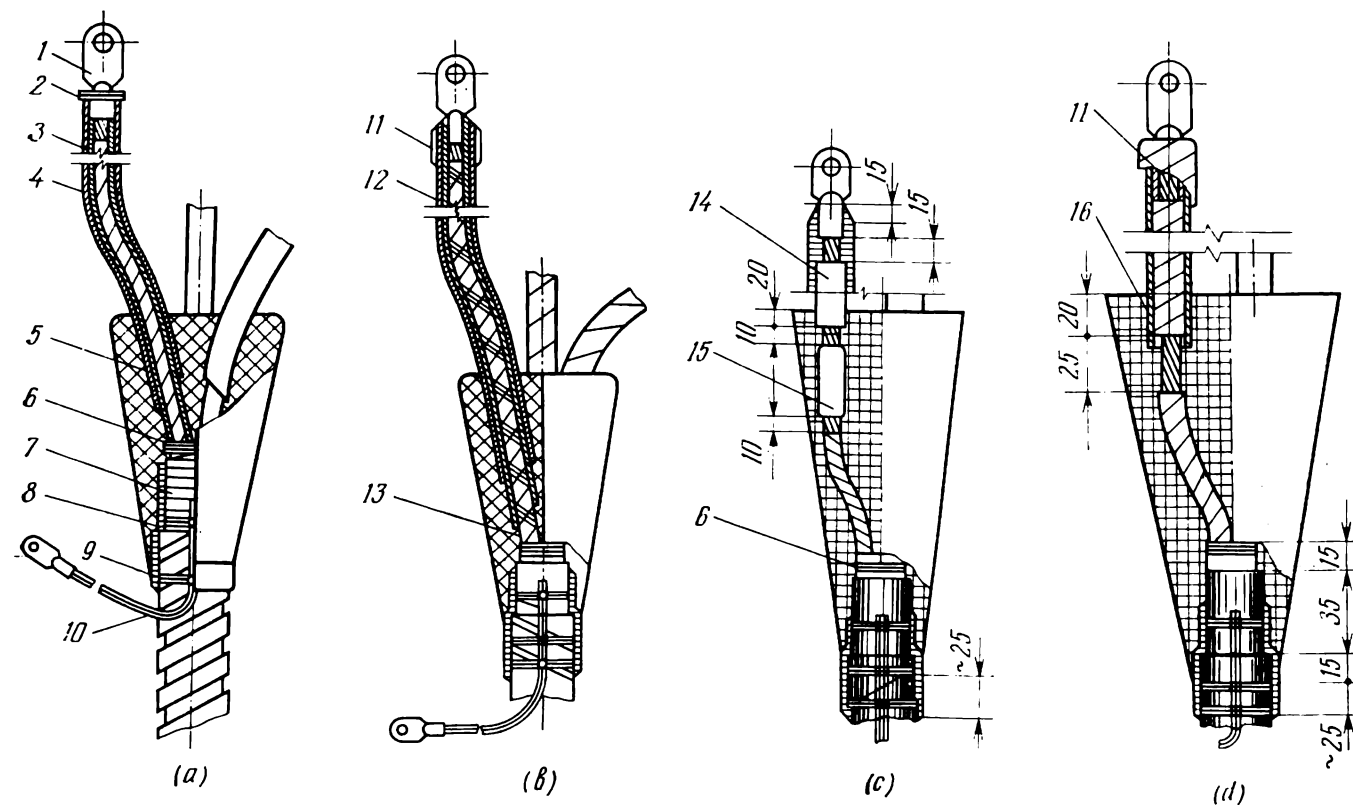


Fig. 95. Epoxy terminations of cables

a—КВЭН; b—КВЭД; c—КВЭП; d—КВЭЗ; 1—lug; 2—band or clip; 3—Najrit rubber tube; 4—conductor in factory insulation; 5—epoxy compound terminator; 6—coarse thread bandage on band insulation; 7—cable sheath; 8—double-layer wrapping; 9—earthing conductor wire band; 10—earthing conductor; 11—cotton tape wrapping covered with epoxy compound; 12—double-layer tube; 13—insulated wire lead; 14—soldered joint of conductors; 15—adhesive PVC tape wrapping; 16—bare portion of conductors

Terminators are fitted on cable ends after cable making-off, which is generally done in the same way as for their jointing in sleeves.

Make-off dimensions for epoxy terminations are selected with reference to Fig. 96 and Table 35.

For mounting the КВЭН termination, the cable conductors are wrapped in adhesive PVC tape in a staggered manner to prevent unfolding of the conductor insulation while Najrit rubber tubes are fitted on them. The inner and outer surfaces of the Najrit tube end to be filled with epoxy compound in a mould are degreased with acetone or petrol, and in 5 or 6 min (after the thinner has evaporated) the degreased surfaces are made rough by treating them with a file or a knife. The inner surface of the other end of the tube to be fitted on the cable lug is treated in the same manner, whereupon the surfaces of both ends of the tube are coated with a thin layer of epoxy compound.

Table 35

**Make-off Dimensions of Cables for Installation
of Epoxy Terminations КВЭн, КВЭд, КВЭп and КВЭз**

Termination size	Dimensions, mm				
	A	N	O	D	B
КВЭн-1, КВЭд-1	$G + 50$	35	15	—	—
КВЭн-2, КВЭн-3, КВЭн-4, КВЭд-2, КВЭд-3, КВЭд-4	$G + 55$	35	20	—	—
КВЭн-5, КВЭн-6, КВЭн-7, КВЭн-8, КВЭн-9, КВЭн-10, КВЭд-5, КВЭд-6, КВЭд-7, КВЭд-8, КВЭд-9, КВЭд-10	$G + 70$	50	20	—	—
КВЭп-1, КВЭп-2	170	35	20	40	—
КВЭп-3, КВЭп-4	210	50	20	45	—
КВЭп-5, КВЭп-6	240	50	20	50	—
КВЭп-7	245	50	20	55	—
КВЭз-1	$G + 55$	20	20	—	90
КВЭз-2, КВЭз-3					95
КВЭз-4, КВЭз-5					120

- Notes. 1. The make-off length of conductor (dimension G) shall be taken depending on jointing conditions, but not less than 150 mm for 1 kV cable, 250 mm for 6 kV cable and 400 mm for 10 kV cable.
2. Dimension D for the type КВЭн, КВЭд, and КВЭз terminations depends on the method of conductor termination.

The paper insulation of conductors is coated with PVC varnish to facilitate pulling the Najrit rubber tube on them. This done, the tubes are pulled on the conductors, shifted for the time being towards the cable root and cable lugs are



Fig. 96. Cable end making-off to receive epoxy terminators

a —КВЭн, КВЭд, and КВЭп; b —КВЭз; 1—cable armour; 2—sheath; 3—band insulation; 4—conductor in factory insulation

fitted on the ends of conductors. The gap formed between the portion with removed paper insulation of conductors and the lugs is filled with cotton tape, each layer of the tape being amply coated with epoxy compound before the next layer

is applied. After this portion has acquired the thickness equal to that of the insulated conductor, the tubular portion of the lug is wrapped in the tape to obtain a thickness at which the Najrit rubber tube will be fitted on the lug with difficulty. The tube is secured on the lug with a metal strip furnished with a clasp or with a band made of several turns of twisted twine.

The sheath step and the upper portion of the armour are degreased with acetone or petrol on the cable end to be terminated, whereupon they are filed down with a bastard file so as to obtain a rough surface for better adhesion with epoxy compound. The sheath and the armour are wrapped in two layers of cotton tape, each layer being generously coated with epoxy compound.

The made-off end of the cable is placed in a detachable mould made in the form of a bell folded from a sheet of polyvinylchloride or vinyl plastic fastened with rubber rings or adhesive tape. Moulds can also be made of any other materials available, such as pressboard, tin, sheet steel, but such moulds must be coated from inside before installation on the cable with a thin layer of transformer oil, solid oil, or petroleum jelly to ensure their easy removal after the epoxy compound has hardened.

The cable conductors are to be checked for their proper mutual arrangement within the mould; it shall be borne in mind that at the exit from the mould (or from the termination after the compound has hardened) the conductors must be equally spaced apart and from the mould edge, the spacing being not less than 7 mm.

The compound is poured into the mould in an even and continuous jet up to the desired level.

After hardening (polimerization) of the compound, the mould is removed from the cable end, the epoxy termination formed is thoroughly examined for cracks, chips, bare portions on conductors and other defects that make the cable unsuitable for carrying electric current.

The KBЭд, KBЭп, and KBЭз terminations are made in a similar way, the difference being in the materials used, methods of bringing the cable conductors out of the epoxy termination, and some mounting operations.

The KBЭθ epoxy termination is used in humid locations. That is why the sealing tubes fitted on conductors are made of two layers; one (inner) layer is made of polyvinylchloride that is resistant to oils and compounds impregnating the cable insulation, and the other (outer) layer of polythene that protects the conductor insulation and the terminator against moisture that might otherwise penetrate inside from the surrounding air.

Prior to fitting a double-layer tube on a conductor, the outer polythene layer of the tube is removed for a distance of 20 mm from the origin of the scarf (Fig. 95b) and then the polyvinylchloride layer on this portion is treated with a file to obtain a rough surface.

The tube is fitted on the conductors, and the PVC step formed in the process is coated with a thin layer of adhesive ПЭД-Б to prevent penetration of cable impregnating compound from getting between the tube layers. This adhesive is also used to coat the inner surface of the tube end to be fitted on the lug. The complete termination is coated with enamel paint ЭП-51 or ГФ-92ХС.

Epoxy terminations *KBЭn* differ from the *KBЭH* termination only in that the cable conductors are brought out through wire leads soldered to them in sleeves within the terminations. Wire leads are made of wire *ИПТМ* having the same cross-sectional area as the cable conductors.

Epoxy terminations *KBЭз* differ from the *KBЭH* terminations in that the solid cable conductors within the epoxy terminator have retainers which are essentially conductor sections with stripped insulation. The cable make-off is shown by Fig. 96b.

While preparing the cable for termination, the conductors are skinned on a section of 25 mm. Najrit rubber tubes are to be long enough to cover the entire tubular portion of the lug on one end and to enter the epoxy terminator for a length of 21 plus 2 mm so as to cover the retainers.

Prior to mounting the mould, the skinned sections of conductors are thoroughly degreased with acetone or petrol to ensure reliable adhesion with epoxy compound.

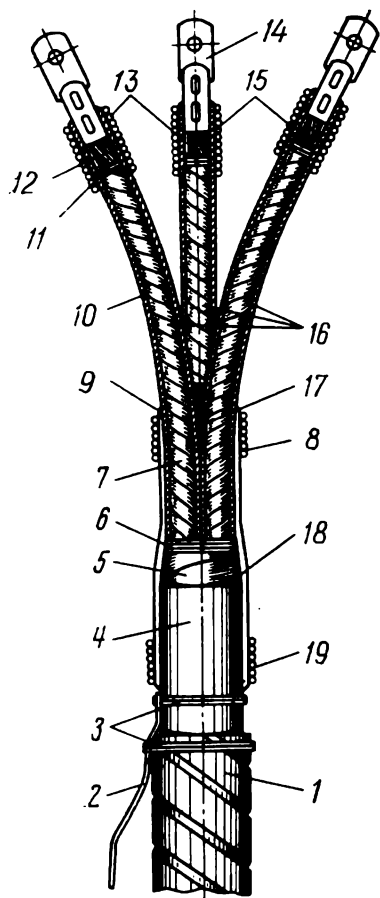


Fig. 97. Type KBB termination

1—cable armour; 2—earthing conductor; 3—wire bands; 4—cable sheath; 5—band insulation; 6, 11—cotton yarn bands; 7—conductor; 8, 15, 19—twisted twine bands; 9—band insulation wrapping sleeve; 10—PVC tape wrapping of conductors; 12—bare portion of conductor; 13—levelling wrapping; 14—cable lug; 16—portion where temporary band is to be applied; 17—filler compound; 18—levelling wrapping

6.8.3. Termination of Cables with PVC Tapes

The type designation of a PVC tape cable termination is KBB (Fig. 97). It is used to terminate paper-covered cables for up to 10 kV service indoors and also outdoors in regions where the ambient temperature never rises above 40°C. In the latter case, the terminations must be protected against direct precipitation and sun rays; also, the difference between the upper and the lower levels of the cable route must not be over 10 m*.

The KBB terminations come in eight sizes, viz., size 1, size 2, and special-purpose terminations.

The KBB terminations shall be made at an ambient temperature no lower than 5°C.

The type KBB, model 1 (KBB-1) terminations are made with the aid of adhesive PVC tape (having a bonding layer), 0.2 or 0.3 mm thick and 15 to 20 mm wide; the model 2 (KBB-2) terminations are made of nonadhesive tape, 0.4 mm thick and 25 mm wide, and of coating compound No. 1 and filling compound No. 2.

The cable end is prepared for termination with PVC tapes in compliance with Table 36 and Fig. 96a.

* If the difference in these levels is higher than 10 m, a special-purpose KBB termination shall be used.

Table 36

Make-off Dimensions of Cable Ends for KBB Terminations

Termination type	Conductor sectional area (mm ²) of cables for voltages, kV			Dimensions, mm (Fig. 96a)		
	1	6	10	A	N	O
KBB-1	Up to 25	—	—	G + 65	30	15
KBB-2	35-50	10-25	—	G + 70	50	20
KBB-3	70-95	35-50	16-25	G + 105	80	25
KBB-4	120-150	70-95	35-70	G + 105	80	25
KBB-5	185	120-150	95-120	G + 125	100	25
KBB-6	240	185	150	G + 125	100	25
KBB-7	—	240	185	G + 125	100	25
KBB-8	—	—	240	G + 125	100	25

Note. See notes to Table 35.

Termination of a cable is started from fitting cable lugs on its conductors by compression, soldering, or welding.

Aluminium conductors are terminated with tubular lugs usually by compression. After the cable lug is mounted, it must be wiped with a rag moistened with petrol, then coated with No. 2 compound, and holes formed on its tubular portion must be filled with cotton yarn or PVC tape and with No. 2 compound. Steps between the tubular portion of the cable lug 14 (Fig. 97) and the factory insulation 7 are levelled off by applying a wrapping 10 made of PVC tape, 7.5 mm wide. To this end, a tape roll, 15 mm wide, is cut into two halves. In the same way it is required to level off the step between the lead or aluminium sheath 4 and band insulation 5 by applying a wrapping to the entire length of the band insulation step.

The outer surfaces of conductor insulation and those of the band insulation are wiped with a rag slightly moistened with petrol, and each conductor is to be wrapped over a portion between the band insulation 5 and the contacting surface of the lug 14 in three layers of PVC tape 10 for conductors of up to 95 mm² area and in four layers of this tape for those of 120 mm² and larger areas. The tape is wound with half the tape width overlapping and so that its tensioning does not reduce the tape width by more than 25 per cent.

The last wrapping layer of each conductor must also cover the entire step of the lead or aluminium sheath.

The wrapping of each conductor is covered with No. 2 compound in a thick layer applied with a brush over a length of 70, 100, and 120 mm (as measured from the band insulation) for cable diameters of 25, 40, and 55 mm, respectively. The compound is applied only to the inward conductor surfaces.

The interconductor space is also filled with the No. 2 compound introduced therein by means of a brush or a spatula. This done, the conductors are assembled

6.8.4. Termination of Cables in Rubber Branch Sleeves

The type KBP termination (Fig. 98a) using rubber branch sleeves and tubes is employed for cables of up to 6 kV laid in premises with normal medium, the difference between the levels of cable ends being not over 10 m.

Rubber branch sleeves (Fig. 98b) are made of Najrit rubber ПЛ-118-11. They are available in nine sizes for three-conductor cables having an insulated conductor sectional area of up to 240 mm² rated at 1 and 6 kV and in three sizes for four-conductor cables having an insulated conductor sectional area of up to 185 mm² rated up to 1 kV.

The cable ends are made off to receive the KBP termination in compliance with the above-given instructions and with reference to Fig. 96a and Table 37.

In preparing for the KBP termination (see Fig. 96), the entire length of the made-off conductor is covered with adhesive PVC tape applied in a staggered manner and meant to protect paper insulation of conductors against damage while putting the branch sleeves on them. The ends of conductors, including their butt ends, are wrapped in a few layers of PVC tape so as to secure the paper insulation and to round off sharp edges in order to facilitate the insertion of conductors into the sleeve branches.

The branch sleeve is put on the cable conductors, with each conductor inserted in the respective branch, whereupon the sleeve body is flanged off over the entire circumference with pliers on a portion where it is to be bonded to the cable, the length of the portion being 25 or 30 mm depending on the sleeve size.

The flanged surface of the sleeve is roughened by a bastard file or a card cloth brush. To this end, the surface must previously be wiped with a rag moistened with petrol.

The cable sheath on the portion between two circular cuts is removed and a coarse thread band is applied to the exposed band insulation.

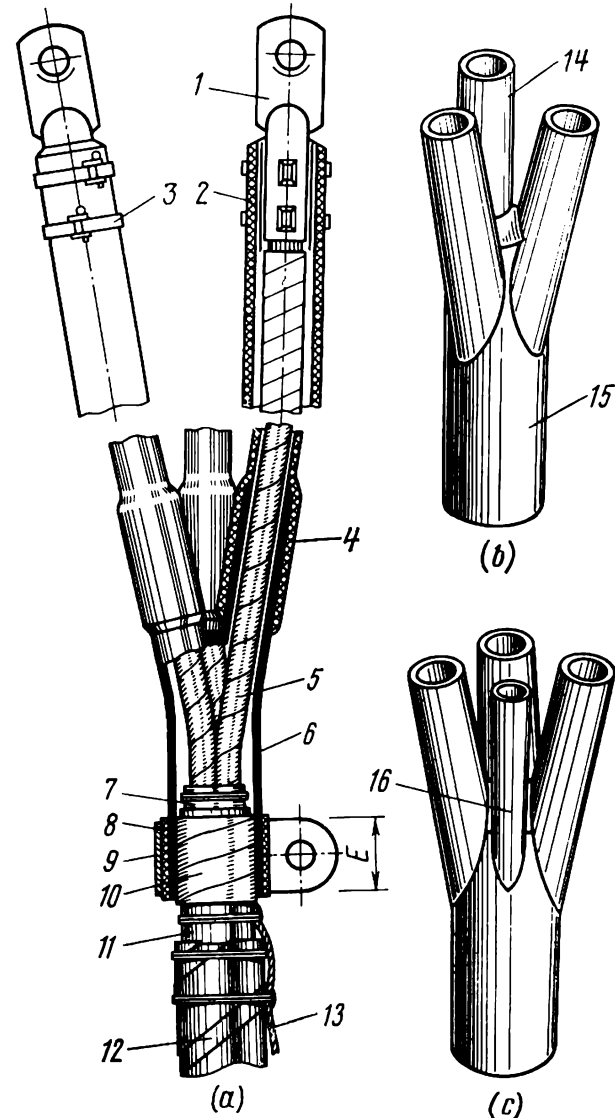


Fig. 98. Type KBP termination in rubber branch sleeves

a—KBP termination general arrangement; b, c—general view of branch sleeves for three- and four-conductor cables; 1—cable lug; 2 and 8—rubber tape wrappings; 3—band; 4—Najrit rubber tube; 5—cable conductor 6—branch sleeve; 7—band insulation; 9—clip; 10—oil-resistant rubber tape packing; 11—cable sheath; 12—armour; 13—earthing conductor; 14—branch piece; 15—branch sleeve body; 16—branch piece for the fourth (neutral) conductor

Table 37

Make-off Dimensions for Type KBP Cable Terminations

Termination size	Dimensions, mm (Fig. 96a)		
	A	N	O
KBP-1, KBP-2, KBP-3, and KBP-4	$G + 90$	65	25
KBP-5 and KBP-6	$G + 95$	70	25
KBP-7, KBP-8, and KBP-9	$G + 105$	80	25
4KBP-1 and 4KBP-2	$G + 80$	60	20
4KBP-3 and 4KBP-4	$G + 85$	65	20
4KBP-5	$G + 95$	70	25

The cable sheath surface to be bonded to the branch sleeve is cleaned off to metal lustre and wiped with a rag moistened with petrol.

The flanged portion of the sleeve and the respective sheath portion are coated with a thin layer of adhesive 88-H. If the cable sheath diameter is smaller than that of the sleeve, the sheath is wrapped in oil-resistant rubber tape, each layer of the tape being coated with adhesive before applying the next one.

Upon the expiration of 5 to 7 minutes required for the adhesive to dry out, the sleeve body is turned out onto the taping. The branch sleeve portion seated on the cable sheath (dimension *E* on Fig. 98a) shall be at least 30 mm for sleeves size I through IV, 35 mm for sleeves size V and VI, and 38 mm for sleeves size VII through IX.

The branch sleeve seated on the cable sheath is packed with a special clip or with two wire bands made of four turns of copper or zinc-plated steel wire, dia 1 mm. The sleeve surfaces to receive the clip or the wire bands are wrapped in two layers of rubberized tape.

The rubber branches at the sleeve root are tied with cotton or rubberized tape for the time being so as to protect the band insulation against damage. Then the cable conductors are set apart and dressed.

To prepare the cable conductors for termination, the ends of the sleeve branches insulating the conductors are turned out on the portion equal to the length of the cable lug tubular part plus 8 mm. To facilitate turning the branches, their surfaces on the portion to be turned out are coated with petroleum jelly or lubricating oil.

Cable lugs are press-fitted, soldered or welded to the conductors, and their tubular portion is wiped with a rag moistened with petrol.

The turned-out portions of the branches are roughened with the aid of a bastard file or a steel brush. Prior to do this, the surfaces must be wiped with a rag moistened with petrol and coated with a layer of adhesive 88-H.

Rolls of oil-resistant rubber tape wound up and coated with adhesive 88-H are fitted in the cavities in the tubular portion of the lugs formed in the course of indentation. If the tubular portion of the lug is smaller in diameter than the sleeve branch and there is a clearance between them, the lug is wrapped in oil-resistant

rubber tape, wiped with petrol, and coated with adhesive 88-H, the number of wrapping layers being as great as required to eliminate the clearance.

The sleeve branch is turned out onto the tubular portion of the lug and sealed with a tube long enough to cover the entire tubular portion of the lug plus the branch portion equal to its two diameters. The tube is bonded to the sleeve branch.

The surfaces of the tube and the branch to be bonded together are roughened, wiped with rags moistened with petrol and coated with adhesive 88-H. After the

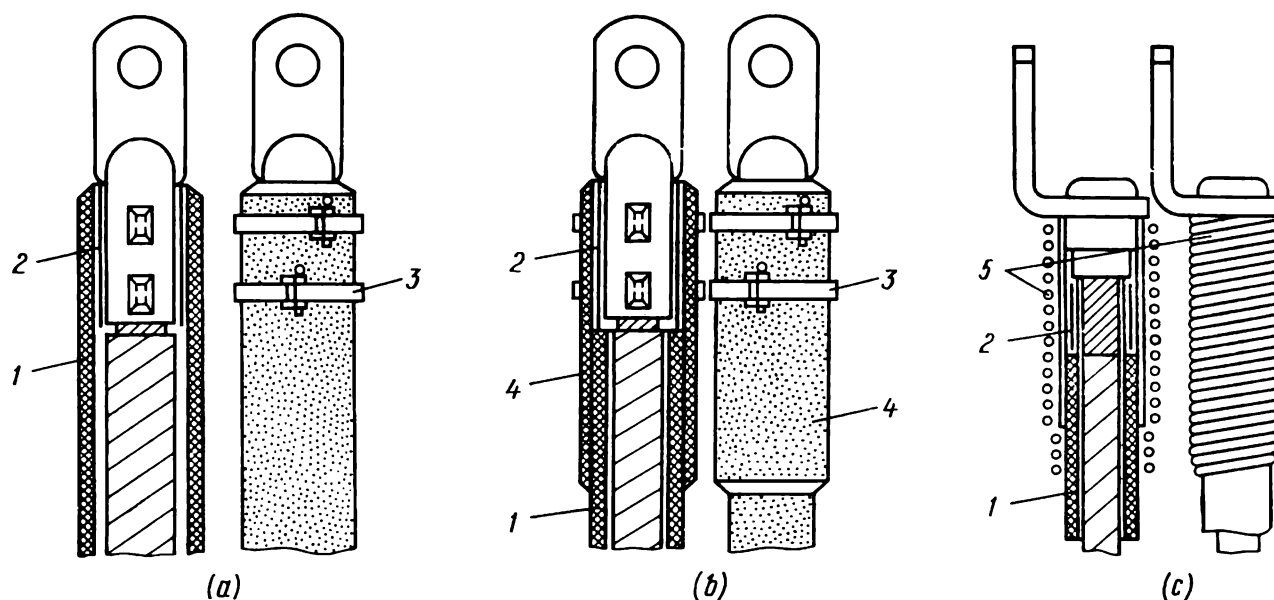


Fig. 99. Methods of sealing rubber tubes on cable lugs in RBP terminations

a—with tube previously turned off; *b*—by means of a tube length; *c*—by applying a twisted twine band to a cast lug; 1—rubber tube; 2—oil-resistant tape wrapping; 3—steel strip band; 4—rubber sleeve; 5—twine band

adhesive coat has dried out, the inner surface of the tube is coated with a thick layer of adhesive 88-H again and the tube is immediately fitted on the lug through its terminal portion.

When cable conductors are terminated with the type JIA cast lugs by welding, the bare portion of the conductor is wrapped in oil-resistant tape that also covers the lug and the conductor insulation.

This wrapping may be tightened by a solid band of twisted twine, dia 1.5 to 2 mm, that is then covered with asphalt varnish. Figure 99*a, b, c* illustrates most widely used methods of sealing rubber sleeve branches on cable lugs.

Special bands composed of a strip, a cotter pin, and a clasp are applied to the surfaces of the rubber sleeve branches. In the absence of special branches use can be made of two wire bands made of four layers of copper wire, dia 1 mm.

6.9. Termination of Cable Conductors

Cable conductors are terminated with lugs attached to them by compression, soldering, or welding. The type of lug and the method of its connection to the conductor depend on the conductor material (copper or aluminium).

The most widely used termination method is by compression which shall be employed wherever possible.

Aluminium conductors of 16 to 240 mm² sectional area are terminated by compression with the type TA and TAM tubular lugs. Copper conductors of 4 to 240 mm² sectional area are terminated with type T lugs. Compression is made by local indentation of the tubular portion of the lug with the aid of compressing mechanisms, such as presses ПГП-7М, ПМП-7, ПГЭП-2, and the like. Prior to compressing, the inner surface of the tubular lug 2 (Fig. 100a) is cleaned with

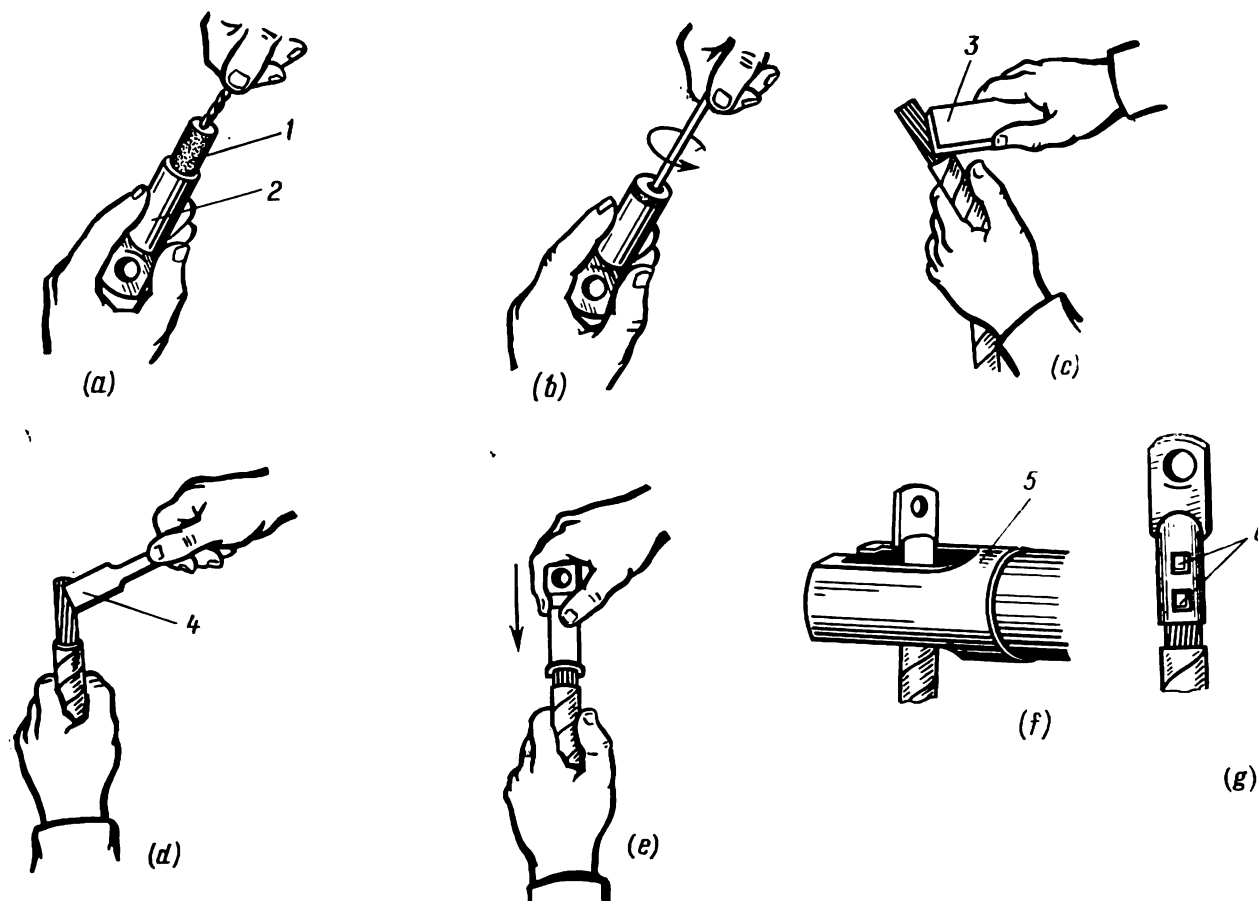


Fig. 100. Termination of aluminium cable conductor by indentation of cable lug
a, b, c, d, e, f, g—successive stages; 1—broach; 2—tubular cable lug; 3—brush; 4—wooden spatula; 5—compressing mechanism; 6—holes

a broach 1 to metal lustre. The cleaned inner surface is coated with quartz-vaseline paste (Fig. 100b) composed of 50 per cent of fine quartz sand and 50 per cent of vaseline. The stripped end of the conductor is cleaned with a card cloth brush 3 (Fig. 100c) and a thin coat of quartz-vaseline paste (Fig. 100d) is applied to it with a wooden spatula 4. The lug is fitted on the conductor as far as it goes (Fig. 100e) and the conductor together with the lug is compressed in a mechanism (Fig. 100f) with a preselected punch and die. The tubular portion of the lug and the cavities formed as a result of indentation (Fig. 100g) are wiped with a rag moistened with petrol.

Copper conductors are terminated with the type T tubular lugs by indentation, proceeding in the same manner as with aluminium conductors terminated with the type TA and TAM lugs, the only difference being that the quartz-vaseline paste is not used.

Aluminium conductors can also be terminated with the type ЛА cast lugs joined to the conductors by resistance or gas welding. Electric and gas welding techniques are principally the same (see Section 5.9 and Fig. 68). For electric welding use shall be made of carbon electrodes, dia 10 to 12 mm, and the type BAMУ flux composed of calcium chloride (50 per cent), sodium chloride (30 per cent), and type K-1 cryolite (20 per cent).

Aluminium and cable conductors may also be terminated with the series П copper lugs joined to them by soldering. For soldering copper lugs to aluminium conductors, use shall be made of the following solders:

(a) type А; the conductor must first be run over with this solder and then soldered to the cable lug;

(b) types ЛО-12 and ЛА-15; these solders can be used without presoldering.

Review Questions

1. What preparatory operations are carried out before placing cables in trenches?
2. What is a cable conduit and how are cables laid in it?
3. Describe the design elements of the type ACE cable and their applications.
4. Describe the methods of making off an aluminium-sheathed armoured power cable.
5. How are cables joined together in a cast-iron sleeve?
6. How is the type КВЭН epoxy termination made?
7. What methods of conductor jointing do you know and where are they used?
8. What safety precautions must be observed when mounting cables?

Installation of Overhead Lines Rated up to 1,000 V

7.1. General Information on Overhead Lines

An overhead line is an arrangement designed for the transmission and distribution of electric power over conductors mounted outdoors on supporting structures of various types. Overhead lines are grouped into those rated up to 1,000 V and over 1,000 V (3, 6, and 10 kV and higher standard voltage classes).

Overhead lines are widely used in the USSR and feature the following advantages: small amount of earthwork usually required for their erection; simple maintenance; use of line supporting structures for supporting the conductors of radio, local telephone communication, street lighting, remote control, and signalling lines; low per-kilometre cost (about 25 to 30 per cent lower than that of cable lines).

Overhead lines are divided into classes I, II, III according to rated voltages and loads connected. Overhead lines rated up to 1000 V are included in class III irrespective of loads connected to them.

In the erection of overhead lines it is essential to take into consideration environmental climatic conditions and expected ice loads on conductors.

Ice loads on conductors of overhead lines may be the cause of very serious outages (breakage of conductors and even destruction of supports).

Regions where ice formation may be expected are characterized by the thickness of ice on line conductors. By this characteristic the following four regions are distinguished: region I with ice thickness on conductors of up to 5 mm; region II, from 6 to 10 mm; region III, from 11 to 15 mm; region IV, from 16 to 20 mm.

Locations where ice thickness on conductors is expected to exceed 20 mm are referred to as critical ice regions.

Conductors of overhead lines of up to 10 kV are suspended from insulators mounted on wood or ferroconcrete pole supports.

By their construction, function, and location on the line, overhead line supports are classed into suspension, angle, tee-off, cross-span, and dead-end supports.

Suspension supports are used to support conductors at the desired height from the earth and are not designed to take forces along the line due to an unbalanced tension of conductors in the event of broken conductors in one of the adjacent spans. Suspension supports are mounted on straight sections of the line and spaced 35 to 45 m apart for 1-kV lines, 50 to 60 m for 6- and 10-kV lines. These distances are referred to as spacings of supporting structures. These supports account for 80% of all support structures on the line.

Angle supports are erected at points where the overhead line makes a turn. These supports are designed to take the component of conductor pulling forces in adja-

cent spans, acting along the bisector of the internal angle formed by conductors.

Tee-off supports are meant to make tee-offs from the main line conductors to feed distant power consumers.

Cross-span supports are used to support overhead line conductors at the points of their crossing.

Dead-end supports are mounted at the beginning and end of the overhead line. They are designed to take forces due to unbalanced tension of conductors along the line under normal conditions.

Use is also made of anchor pole supports that are distinguished from those described above by higher strength and more intricate construction.

Anchor supports may function as suspension, angle, tee-off, cross-span, and dead-end supporting structures. Anchor suspension supports are erected with their legs placed either along or across the line; in the former case, the support takes unbalanced forces created by conductors along the line; in the latter case, the anchor support takes conductor forces perpendicular to the line. The spacing between the two anchor supports is referred to as anchor span. On straight sections of an overhead line of medium complexity rated at 1 kV, the anchor span is 150 to 180 m, and on the sections of lines rated at 6 and 10 kV the anchor span is 250 to 280 m.

Anchor supports raise the mechanical strength of overhead lines. The anchor support takes heavy loads due to unbalanced tension of conductors if one or more conductors are broken so that the resulting faults are confined within a single span.

Supports of all types can be made with struts, with single-wire or stranded guys.

In selecting the number of supports, their type, the spacing between them, the following shall be taken into account: complexity and configuration of the line, quantity, material, and cross-sectional area of conductors to be supported, environmental climatic conditions, density of population of the area over which the overhead line is routed, reliability and operational safety considerations.

The overhead line conductors must be elevated above the ground and suspended at an appropriate distance from it and from terrain objects crossed by them or those standing parallel to them. These distances are called vertical clearances of conductors, crossing clearances, and safety clearances.

The vertical clearance of an overhead line conductor is the distance from the conductor at the low point of the sag to ground.

The crossing clearance of overhead line conductors is the shortest distance from the conductor to the object it crosses. When a conductor crosses objects located under the line, such as roads, rivers, etc., this clearance is determined as the distance from the lower conductor of the line to the object being crossed; when the line crosses objects located above it (when routed under a bridge, under overhead power transmission lines rated at higher voltages, etc.), this clearance is determined as the distance from the upper conductor of the line to the object being crossed.

The safety clearance of line conductors is the shortest safety distance from the line conductor to the objects (buildings, scaffold bridges, surface utilities, etc.) running parallel to the overhead line.

To afford the desired mechanical strength of overhead lines of up to 1,000 V, use is made of single and stranded conductors of the following minimum cross-sectional areas: 16 mm² for aluminium conductors; 10 mm² for steel-core aluminium and bimetallic conductors; 25 mm² for stranded steel conductors; $\frac{7}{8}$ dia 4 mm for single steel conductors.

Unstranded conductors, single steel conductors of a diameter larger than 5 mm and bimetallic conductors of a diameter larger than 6.5 mm shall never be used.

Whenever selecting the line conductor material and cross-sectional area, a number of calculations shall be made, including the calculation of mechanical load. The main purpose of calculating the mechanical load is to ensure the desired mechanical strength of the line at minimum constructional cost. The calculations include the determination of nominal strain in conductors at various climatic effects, conductor sag, line conductor distance to ground and to buildings. Dead mass of conductors, ambient temperature, and wind pressure are also taken into account.

Calculation of loads for the mechanical design of conductors shall better be made in terms of the so-called specific load, φ_c , per metre of conductor length and per mm² of its cross-sectional area (φ_c , kgf/m·mm²).

The following calculation equations shall be used to determine the specific loads on line conductors:

- (a) due to the conductor dead mass, φ_1 , $\varphi_1 = \frac{G}{S}$;
- (b) due to the mass of accumulated ice, φ_2 , $\varphi_2 = \frac{3.14b(a+b)\varphi_0}{1,000 S}$;
- (c) due to the conductor dead mass and the mass of accumulated ice, φ_3 , $\varphi_3 = \varphi_1 + \varphi_2$;
- (d) due to the wind pressure on conductors in the absence of ice, φ_4 , $\varphi_4 = \frac{P_0 d}{1,000 F}$;
- (e) due to the wind pressure on conductors loaded with ice, φ_5 , $\varphi_5 = \frac{P_0(d-2b)}{1,000 F}$;
- (f) due to the conductor dead mass and the wind pressure on conductor in the absence of ice, φ_6 , $\varphi_6 = \sqrt{\varphi_1^2 + \varphi_4^2}$;
- (g) due to the conductor dead mass and the wind pressure on conductor loaded with ice, φ_7 , $\varphi_7 = \sqrt{\varphi_3^2 + \varphi_5^2}$.

The following designations are used in these equations: G is per-metre mass of conductor, kg; φ_0 is ice density equal to 0.9; S is conductor cross-sectional area, mm²; a is conductor external radius, mm; d is conductor diameter, mm; b is ice thickness, mm; P_0 is wind pressure on conductor, kPa; $P_0 = (v^2/16) F$, where F is conductor diametric sectional area, mm², v is rated wind velocity equal to 10 mps for ice regions I and II, and 15 mps for ice regions III, IV, and critical ice regions.

Conductors of different materials or of different cross-sectional areas must be joined together only after they are mounted on supports. These joints must not suffer mechanical loads.

Phase conductors may be arranged on a supporting structure in any desired sequence; the neutral conductor is usually located below the phase conductors, and the street lighting conductors below the neutral conductor. Fuses installed on supporting structures are arranged below conductors. Vertical clearances between

conductors mounted on supporting structures in ice regions I and II shall be at least 400 mm; horizontal clearances between conductors shall be at least 200 mm for up to 30 m spans and at least 300 mm for over 30 m spans.

For ice regions III and IV, the vertical clearances between conductors shall be 600 mm, and the horizontal clearances 400 mm.

The distance from the conductors to the supporting structure surface or to its separate elements (crossarm, saddle, brace, etc.) shall be at least 50 mm.

Protection against surge voltages in isolated-neutral networks is afforded by earthing the hooks and pins of phase conductors and those of the ferroconcrete line support accessories. In earthed-neutral networks, these items are connected to the earthed neutral wire.

The earthing tee-off wire on the overhead line support shall be at least 6 mm in diameter. The earthing system resistance shall not be higher than 50 Ω .

Earthing tee-off wires shall also be made on supports where the line is branched off to entries into crowded premises or those containing valuable materials or products, such as store houses, garages, etc., and on dead-end supports of lines branched off to lead-ins.

7.2. Marking Out Overhead Line Routes and Making Holes for Pole Supports

7.2.1. Laying Out the Overhead Line Route

Laying out the overhead line route includes all the jobs associated with the preparation of maps and profiles of the line route and pole setting schedule.

The line shall be routed so as to ensure normal conditions for transport and pedestrians, easy maintenance and repair of all the line elements.

Distances from the supporting structures and conductors to various underground and surface utilities are given below.

Adjacent object	Minimum clearance, m
Underground pipelines, sewer pipes, and cables	1
Fire hydrants, water posts, underground conduit man-holes	2
Petrol pumps	5

The overhead line route is surveyed starting from the determination of the direction of the first straight section of the line with the aid of a theodolite, this being followed by setting up two temporary survey stakes, one at the beginning and the other at a distance of 200 to 300 m from the former (depending on the visual range). Temporary survey stakes are erected at the locating points of pole supports indicated in the project along the direction obtained, and these stakes are sighted from both the ends of the line section to check them for correct positioning in the range of the overhead line being erected. Then these stakes are removed and replaced by bench marks. Each bench mark bears its number and the project number of the

support that is to be installed in this very point. Bench marks are to be arranged in the centre of the future pole holes.

Holes for single-pole and A-pole supports made along the line range must be located with their longer side along the line route, while holes for A-pole supports to be installed across the line range shall be located with their longer side perpendicular to the line route.

At the point where the line changes its direction, its angle of turn shall be laid out on the A-pole angle support in advance. To this end, assume that the pole support is the apex of an angle (Fig. 101a) and plot equal lengths AB and AC along

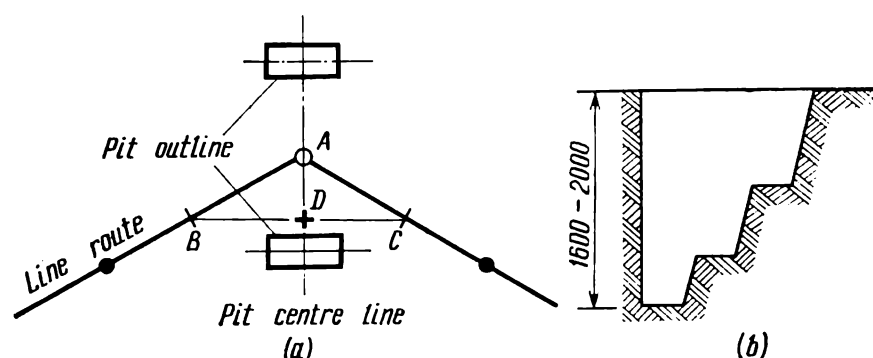


Fig. 101. Pits for pole supports

a—layout of pit for angle anchor pole (A-pole) support; b—finished pit for single suspension pole

the sides of the angle. Then interconnect points B and C and connect the centre of the BC length with point A . The AD straight line is the bisector of the angle. The holes must be located on this bisector and equally spaced from point A at a distance determined by the separation of the pole support legs. It is good practice to use special templates for laying out the holes for A-pole supports so as to ensure minimum time and maximum accuracy. The angles of turn of the line are designated by angle symbols. The angle bench mark bears its sequence number, the angle of turn of the line, and the project number of the support.

The actual lay-out of the line made on site is compared with the project lay-out. Deviations from the project are eliminated or co-ordinated with the design office, whereupon holes can be made.

7.2.2. Digging Pole Holes

Holes for overhead line pole supports can be dug by means of special machines. Round holes for single-pole supports are made by means of automatic hole augers and power-driven excavating machines. Rectangular holes for anchor supports are made by means of single-bucket excavators. Manual labour may be admitted only where the scope of work is small and suitable mechanisms cannot be used because of a confined space, danger of injuring adjacent objects (such as underground lines, surface structures, etc.), or danger of accidents.

Work involved in the erection of overhead lines shall be organized so that poles can be installed immediately as soon as their holes are ready to receive them, be-

cause holes left open for a long time may be the cause of accidents with people and animals. Besides, moisture accumulates readily at the bottom of open holes.

When using an automatic auger, the holes are bored in a few steps. First the auger is driven into the earth through a depth of 0.4 or 0.5 m and raised together with the earth, then it is run at a higher speed to scatter the earth. After that the auger is driven into the earth again through another 0.4 or 0.5 m. These operations are repeated until the hole of the desired width and depth is obtained.

The hole depth is specified by the project and depends on the character of soil, height and purpose of the support, environmental climatic conditions, number of conductors to be supported and their cross-sectional area, extreme conditions, etc. Outer surface boundaries of holes depend on the natural slope. The area of the hole base shall be large enough to ensure that the butt end of the pole support can be moved through 10 to 15 cm across the line so as to install it accurately within the line range.

Holes for angle and dead-end supports are made so that the intact wall of the hole is located on the side of the line conductor pull.

On steep slopes where the earth is subject to washing out with running off water, holes are made manually, the longitudinal centre line of the pole hole being normal to the slope and that for the hole of the pole brace (saddle) normal to the hole surface.

A hole made manually is dug in steps (Fig. 101b) to facilitate the work and to make it easier to install a pole in it.

In flood-water areas where the soil may be washed out, the pole supports must be reinforced by additional earth and by cabblesone placed around the pole.

For manual digging, use is made of a manual auger, an entrenching shovel, a crowbar, an ice chiesel, and other tools. Where the hole is longer than 2 m or the soil is saturated with water, and also where the workmen are expected to work in the hole for a long period of time, the hole walls must be timbered with boards, at least 25 mm thick, and with braces, at least 100 mm in diameter.

In cold seasons holes shall be made and pole supports erected in them within the shortest time possible to avoid freezing of the hole bottom, otherwise the soil may thaw and subside in future causing the pole to go down, with the result that the conductor vertical clearance will not be kept within the specified limits. At sub-zero ambient temperatures, the hole depth is decreased by 15 to 20 cm as compared with the design depth so as to prevent freezing of the soil. The soil not excavated in advance is removed from the bottom of the hole just before erecting the pole.

Pole holes are to be made observing safety precautions, especially after a depth of 0.4 m is attained, for there is danger of injuring underground pipelines or structures. If an underground cable or a pipeline is found or if a smell of gas is sensed, the work must be immediately discontinued and the crew leader informed on the fact to obtain further instructions.

7.3. Assembling and Installation of Overhead Line Pole Supports

For the installation of overhead lines rated up to 1,000 V, use is made of wood and ferroconcrete pole supports. Wood pole supports (Fig. 102*a, b, c, d*) are available in various constructions.

Wood pole supports are usually made of soft wood (larch, fir, pine, etc.). Pine logs for main components of pole supports such as poles, stub poles, cross-arms, braces, for overhead lines rated at up to 1,000 V shall be at least 14 cm in diameter. The diameter of logs for auxiliary pieces, such as saddles, auxiliary beams, etc., shall be at least 12 cm in diameter. The service life of wood is short. So, in the middle part of the USSR the service life of pine-wood pole supports, unless suitably treated, is about 5 years. Wood is generally attacked by fungi and by some insects, such as horntails, black horn-tailed beetles, and termites. The service life of wood pole supports can be increased as much as three or four times by giving them a preservative treatment with antiseptic chemicals. The materials employed for wood preservation are creosote oil, sodium fluoride, uralite, donolite, and the like.

Wood pole supports are fabricated, given a preservative treatment, and assembled on special fields or at factories and delivered to the installation sites by timber trucks. Single-pole supports are delivered in an assembled condition, while multipole (A-pole and the like) supports are assembled partially. They are fully assembled on the installation site. Prior to assembling, all the components are thoroughly examined for damaged preservative and rust-preventive coatings, stripped thread on bolts and studs, deep cavities on metal clips and wire bands, etc. Most susceptible to decay are parts of a wood support 30 or 40 cm above and below the ground line, where the wood is most intensively affected by varying precipitation and soil water.

To save wood, poles are often joined to wooden or ferroconcrete stub poles. Such combined pole supports are robust constructions that make the overhead line more reliable in operation and raise its service life. A pole is joined with one or two stub poles by means of wire bands or clips (Fig. 103*a, b*). For joining a wood pole with a wooden stub pole, the butt end of the pole is cut flat over a length of 1.5 or 1.6 m to obtain a plane 100 mm wide. The same treatment is given to the wooden stub pole on its top part. The planes obtained on the pole and on the stub pole must end in perpendicular saws. The joint between the pole and the stub pole must be tight, without any clearances. Band lines are marked on both the parts, and small holes are made for band clamping bolts*.

The surfaces on the pole and stub pole to receive the wire bands (50 to 60 mm wide) are cleaned off to remove any roughness for better bracing of these parts with bands. Bands are applied to the joint at two points 200 mm down from the stub pole top and 250 mm up from the pole butt. Wire bands are to be spaced 1,000 to 1,100 mm apart. Bands are made of soft zinc-plated steel wire, dia 4 mm, or rolled steel wire, dia 5 or 6 mm. A band consists of several turns of wire applied to the joint to brace together the pole and the stub pole and twisted or tigh-

* Holes for bolts are made only when wire bands are braced with bolts and not by twisting.

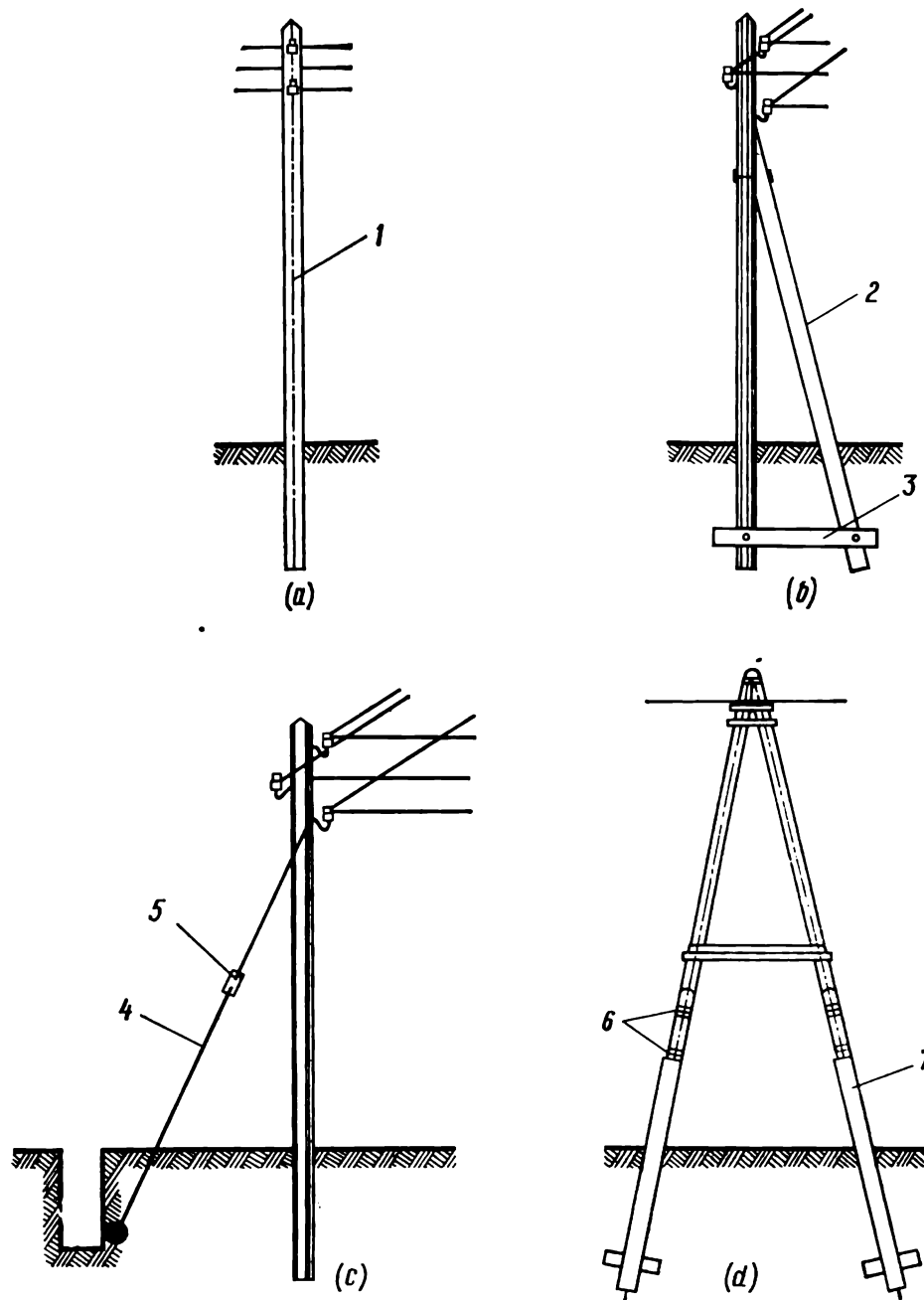


Fig. 102. Design alternates of 1,000-V overhead line wood pole supports
a—single suspension pole support; b—strutted angle pole support; c—angle pole support with guy; d—anchor A-pole support; 1—pole; 2—strut; 3—cross-beam; 4—wire guy; 5—sag adjuster; 6—bands; 7—stub poles

tened with a through bolt. The number of wire turns depends on the wire diameter. Each band must have eight turns of 6-mm wire, 10 turns of 5-mm wire, or 12 turns of 4-mm wire.

The wire length for one band is found from the equation

$$L_b = 2.6n (D_1 + D_2)$$

where L_b is wire length, cm; n is number of turns per band; D_1 and D_2 are diameters of the pole and stub pole at the point where the band is to be applied, cm.

The wire band is applied to the pole support as follows. One end of the wire is bent over a length of 3 cm at right angles and driven into the stub pole*;

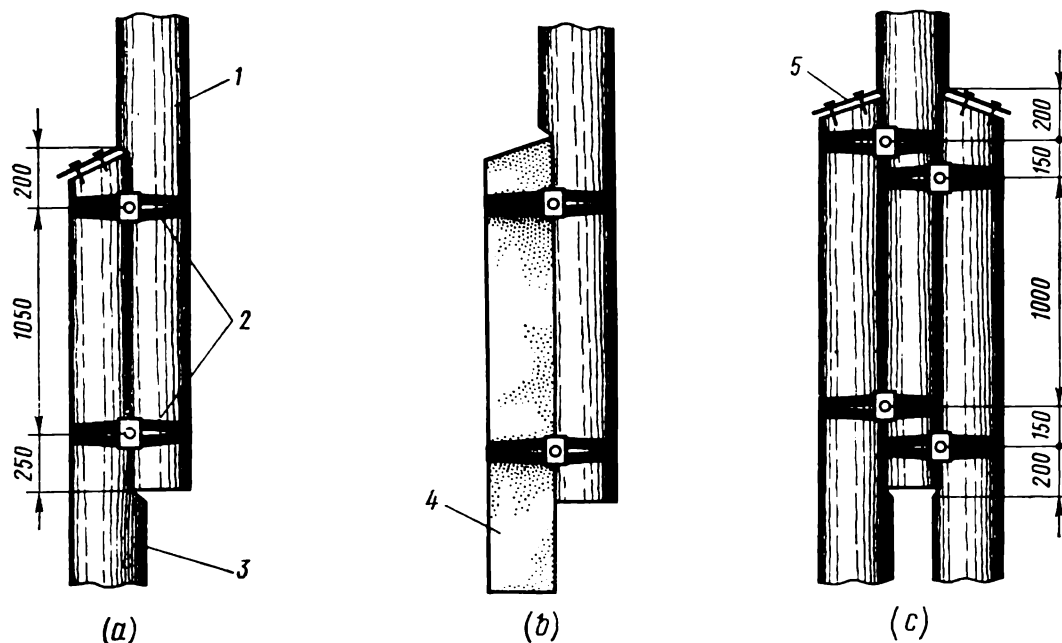


Fig. 103. Methods of jointing wood pole supports with stub poles

a—one wooden stub pole; b—one ferroconcrete stub pole; c—two wooden stub poles; 1—pole; 2—bands; 3—wooden stub pole; 4—ferroconcrete stub pole; 5—tar paper layer

the desired number of turns is wound, pushed apart at the centre, a curved-end crowbar is inserted into the space between the turns, and the latter are twisted together. Then the second band is applied using the same procedure, whereupon the support is turned over and the wire bands are twisted together with the crowbar on the other end of the support. In this way, the wire bands are tightly braced at the joint between the pole and the stub pole. As an alternative to twisting, the wire bands can be braced together by means of a shaped-head bolt with a washer and a nut.

Bracing with two stub poles (Fig. 103c) is made in the same way, the only difference being that the pole is planed on two sides. Each stub pole is secured to the pole by separate wire bands that are accommodated in grooves, 6 to 8 mm deep

* When a ferroconcrete stub pole is employed, the end of the wire band is driven into the pole.

and 60 or 65 mm wide, made on the stub poles in advance. The mating surfaces of the pole support components, grooves, notches and dawks are to be given the preservative treatment. Washers shall be placed under the nuts and bolt heads. Wood under the washers shall be planed but not cut off. Three metres up from the ground line the thread on the bolts extending from the nuts is lock-punched. Bolts extending from the nuts by more than 10 mm are sheared and lock-punched. Exposed metal surfaces of pole supports are double coated with asphalt-bituminous varnish.

To facilitate application of wire bands, the pole must be elevated 20 to 30 cm above the ground line and the stub poles are to be temporarily attached to the pole with screw clamps (Fig. 104a).

Pole supports are outfitted by their manufacturer, but often this is done on site of installation so as to prevent damage to insulators and line accessories in transit. Outfitting procedures include marking out the locating points of hooks, drilling holes for hooks in the pole support and fitting hooks with insulators in these holes.

Locating points for hooks on supports are marked out by means of a template made of a piece of rectangular aluminium strip, 3 or 4 mm thick. The template (Fig. 104b) is placed with its short bent end on the top of the support first on one end, then on the other, and locating points for hooks are marked out against even- and odd-numbered holes of the template. Holes in cross-arms for pins are also marked out by means of a template.

Holes are drilled in the pole support by means of a motor-driven tool; if an electric power source is not available on site, use can be made of an auger of appropriate size or of a special tool (Fig. 104c). The diameter of the hole drilled in the pole support must be equal to the inner diameter of the hook thread. The hole depth must be three-fourths the length of the hook threaded portion. The hook must be driven into the pole with its entire threaded portion plus 10 to 15 mm. For driving in the hooks, use shall be made of a tap wrench (Fig. 104d).

Insulators are secured on hardware (hooks, pins) in workshops or on site of installation when outfitting the supports*. Insulators must be free from cracks, chipped porcelain, unremovable dirt, and other defects. Dirty insulators must be cleaned. Metal brushes, scrapers, or other metal tools must never be used for the purpose. In most cases dirt is removed from insulators with a dry rag moistened with water. Fast contaminants, such as rust, etc., are removed with a rag moistened with hydrochloric acid. Linemen dealing with hydrochloric acid must put on acid-resistant rubber gloves and goggles.

Insulators and hardware (Fig. 105) are selected with due regard for the rated loads and tension of conductors, ice region class (mass of ice expected on conductors), wind pressure on conductors, and other factors. The following margins of safety with respect to the breaking load are taken: 2.5 at normal tension of conductors and 3.0 at weak tension.

Wood pole supports are widely used for overhead lines, especially in regions rich in wood. Their service life, however, is rather short, as has already been men-

* For the attachment of insulators to hardware refer to Section 5.6.

tioned above. That is why they are gradually superseded by ferroconcrete supports whose service life is as long as 50 to 60 years.

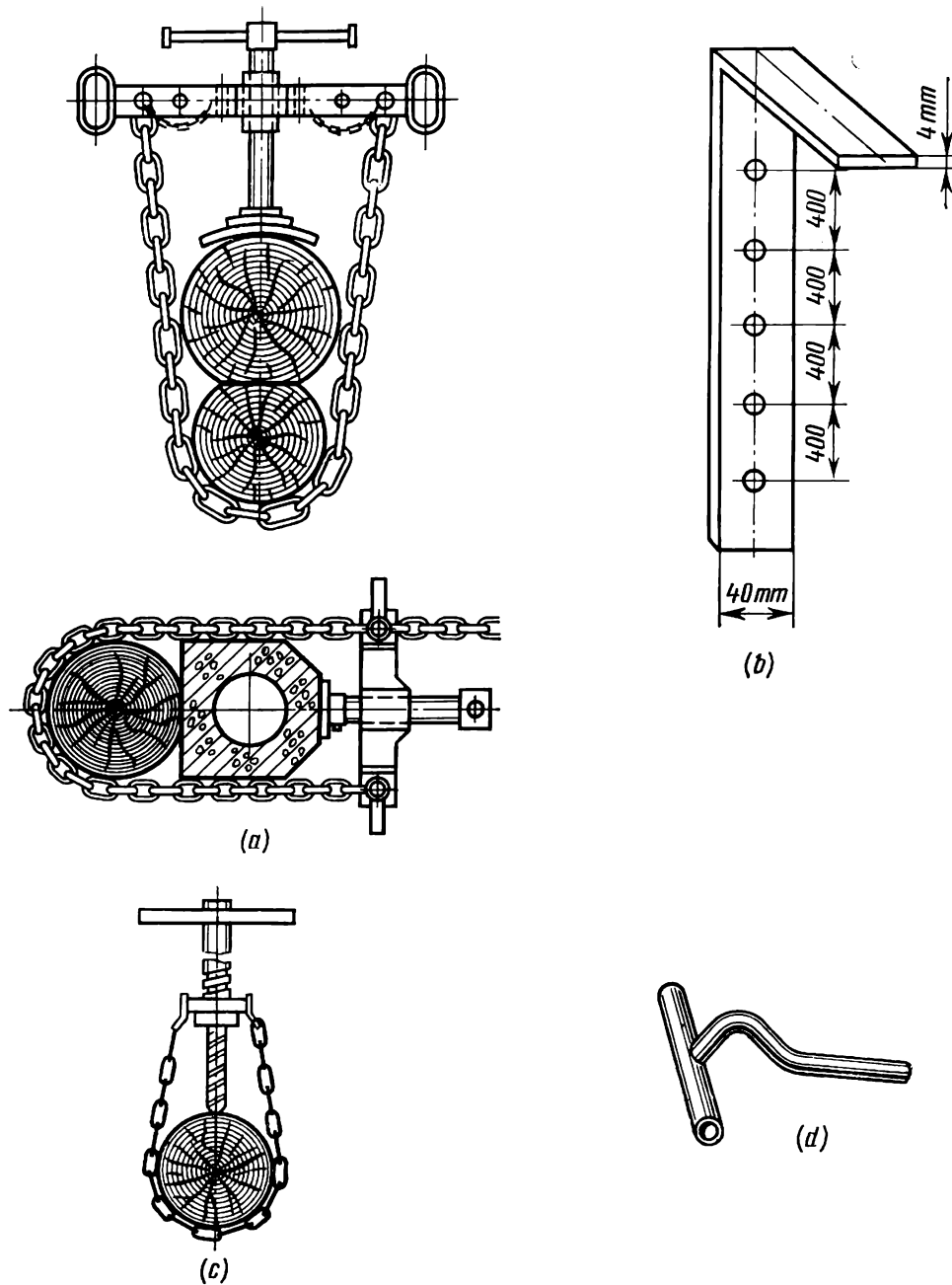


Fig. 104. Tools for assembling and outfitting wooden poles

a—screw clamp for temporary fixation of a pole to a wooden and ferroconcrete side piece; **b**—template for marking off hook holes; **c**—manual drill for making holes in a wooden pole; **d**—tap wrench for driving hooks into a pole

Ferroconcrete pole supports for overhead lines of up to 1 kV are of a tapered shape and have a round or rectangular section (Table 38). To reduce the mass of the pole, it is made hollow over most of its length. Ferroconcrete supports are furnished with a robust reinforced-steel framework that functions to increase

their mechanical strength. Conductors are suspended from them by means of yokes or hooks; in the latter case, holes to receive the hooks are made in the pole while fabricating it. A special lead welded to the framework hardware is provided

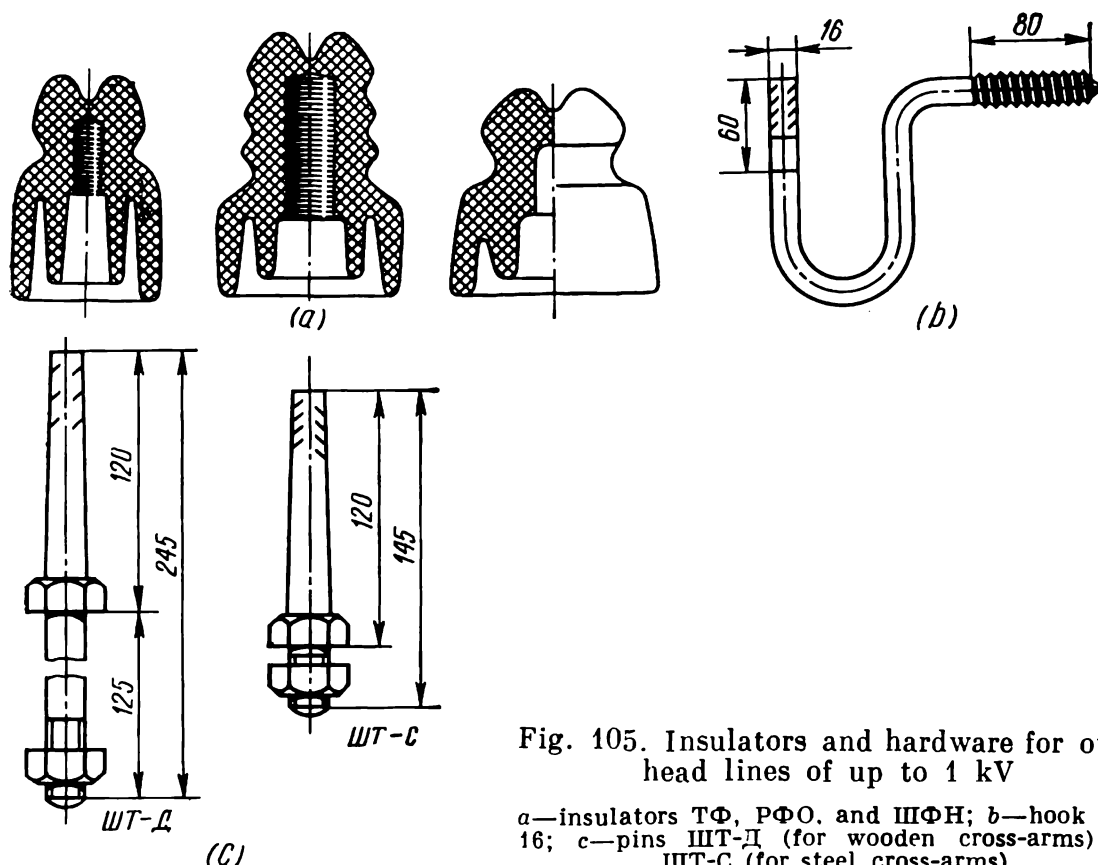


Fig. 105. Insulators and hardware for overhead lines of up to 1 kV

a—insulators TΦ, PΦO, and IIIΦH; b—hook KH-16; c—pins IIIТ-Д (for wooden cross-arms) and IIIТ-С (for steel cross-arms)

to connect the neutral wire of an earthed-neutral line. The ferroconcrete pole supports are erected in prefabricated foundations or directly on the ground with ferroconcrete slabs placed under the pole.

Ferroconcrete supports are actually outfitted in the same way as wood pole supports, the difference being in some auxiliary operations. Pole supports must be fully outfitted before being raised and erected in holes, which makes it possible to employ all necessary tools and mechanisms and to facilitate the work of line-men.

7.4. Hoisting and Installation of Pole Supports

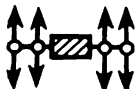
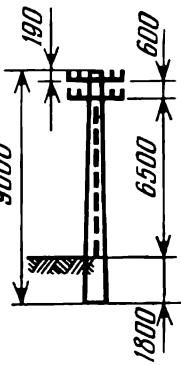
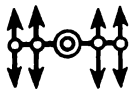
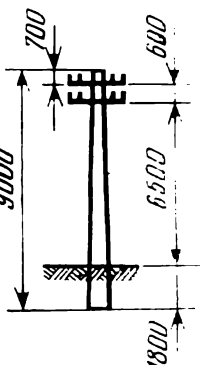
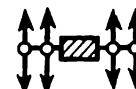
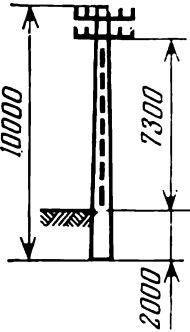

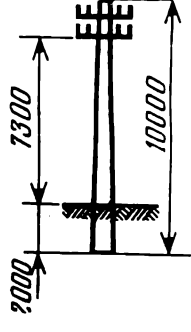

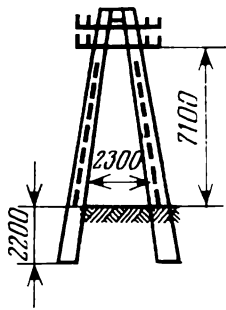
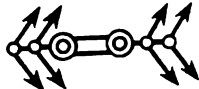
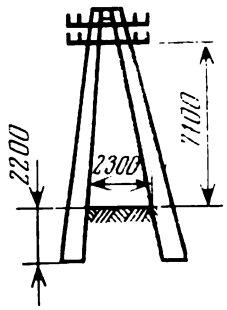

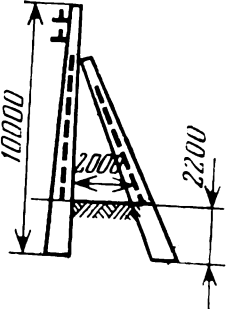

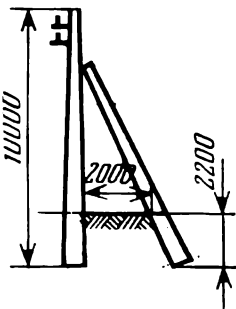
Prior to starting the erection, clear the way for vehicles delivering the supports and for haulage and hoist mechanisms used to erect the supports in their holes.

Check hoisting and haulage equipment and fixtures for condition and make them ready for use. Pay particular attention to the condition of winches, pulley blocks and tackles, wire ropes and cables, bracing wires, etc.

For raising the supports and erecting them in holes, make use of cranes and hoisting mechanisms, types БМУ-2, БКГМ-АН-63, and the like.

Table 38

Ferroconcrete Pole Supports of Overhead Lines

Support type	Rectangular-section		Round-section	
	diagram	sketch	diagram	sketch
Suspension				
Suspension, high				
Angle				
Dead-end or anchor				

In hoisting and erecting single-pole supports (Fig. 106a), place the crane 3 or 4 m away from the centre line of the route.

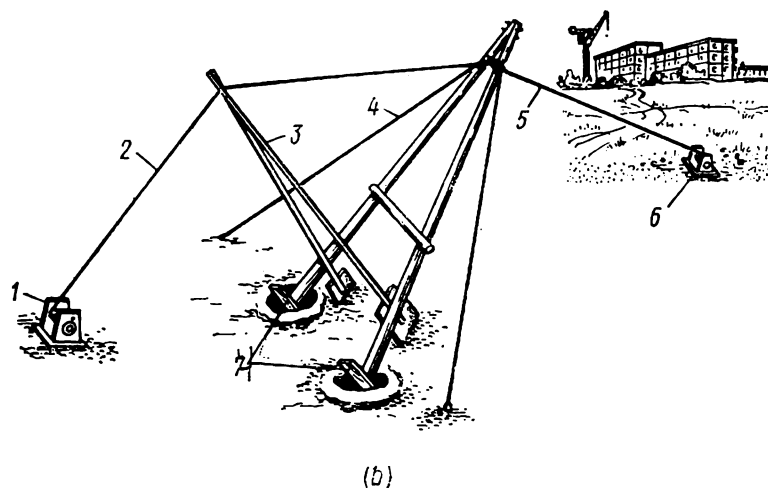
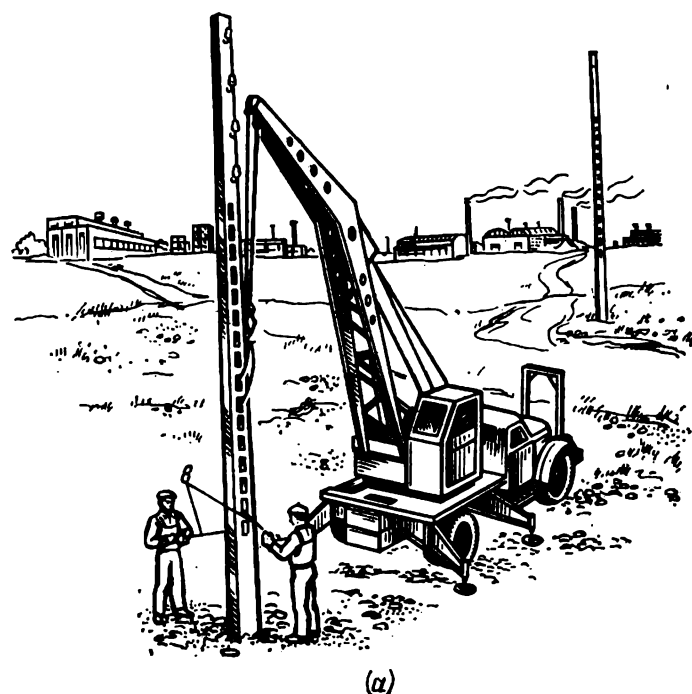


Fig. 106. Raising overhead line pole supports and setting them in holes

a—ferroconcrete single-pole support installed by means of a crane; *b*—double wood A-pole support installed by means of winches and a falling derrick pole; 1—pulling winch; 2—pulling rope; 3—falling derrick pole; 4—guy rope; 5—braking rope; 6—braking winch; 7—boards placed under the derrick pole legs; 8—wire hooks for adjusting the support in position

Lay the assembled pole support at the hole and attach raising slings to the pole slightly above its centre of gravity, and guy ropes to the pole head. The guy ropes will be required to level off the support. For the connection of wire ropes and their attachment to hoisting mechanisms and to supports, make use of implementary

grips, thimbles, and clamps. For raising ferroconcrete supports, grip their poles at two points. Raise the support with the crane until it assumes the vertical position and set it by means of guy ropes within the hole in the marked-out position.

When erecting A-pole supports by means of a falling derrick pole (Fig. 106b), lay the support flat at the holes so that their footings are 0.3 m away from the hole edges. Attach boards to the walls of the pole holes to slip the poles over them when being erected therein. Secure two braces and a braking rope to the top of the support. The braces are required to prevent sideways movement of the support while raising it, and the braking rope to maintain it in the vertical position when fully raised. Lay the falling derrick pole along the line route with a downgrade of 15 to 20 deg towards the support. Place a board, 40 to 50 mm thick, under each leg of the derrick pole to protect the soil against being caved in by the pole legs when the support is being raised. Pass the raising line running from the winch over the top of the derrick pole and make it fast on the support top. This done, give the support a trial lift to a height of 0.5 to 0.8 m from the ground to make sure that the raising line is reliably secured and that the derrick pole and the support are correctly set in position. The derrick pole height must be 1 or 2 m greater than the distance from the centre of gravity of the support to its footing.

Prior to raising the support, attach the derrick pole to its cross-beam by means of a rope with a pulley block so as to hold it in position after the support is raised.

Raise the support slowly, without jerks; in the process keep an eye on the support legs and make sure that they slip over boards and enter the holes. After the derrick pole has become inoperative, the support is further raised by the pulling line. As the top of the support approaches the "balance" point, tighten the braking rope and see to it that it is properly tensioned until the support is set vertically.

The rope diameter is found by calculations. The minimum size of raising and guy ropes, however, for single-pole supports of 1-kV overhead lines shall be 14 mm for pulling ropes and 12 mm for braking ropes and braces or guy ropes.

If the required mechanisms are not available and a small number of single-pole supports is to be erected, this work may be done manually provided appropriate safety precautions are observed to avoid falling of supports and to exclude any accidents.

For raising a single-pole support manually, first lift it by hands so that its top is raised 2.5 or 3 m above the ground. Then support it by means of gaffs and grips. Gradually raise the support by alternately holding it with gaffs and grips. In the action, the pole butt end must slip over a vertical board fitted in the pole hole and get into the hole. As soon as the pole is set with its butt end on the bottom of the hole, position it in the correct vertical plane and check if it is positioned in the route range, if the pole-to-stub pole joints are along the line and if there is any projecting curvature on the pole.

In erecting the supports, bear in mind the following:

(a) the centre lines of the supports must be vertical both along and across the line axis; allowable deviation from the vertical plane for wood pole supports is 5 mm, and for ferroconcrete supports 1 mm per metre of the support length;

(b) the cross-arms shall be arranged horizontally; permissible deviation from the horizontal line is maximum 10 mm per metre of the cross-arm length;

(c) the supports must be arranged within the line range; permissible deviation from the line range is maximum 100 mm.

After plumbing and adjusting the support in position, back-fill the hole in layers of 30 to 40 cm, and ram the earth in one layer at a time. Then take down the tackle. Do not raise supports in stormy wind, nor take down the tackle unless the hole is fully back-filled.

7.5. Installation of Overhead Line Conductors

Overhead lines rated up to 1 kV are usually wired with aluminium, steel-core aluminium, and steel conductors whose basic characteristics are given in Table 39.

Table 39

Characteristics of Conductors Used for Overhead Lines of Up to 1 kV

Type	Dia, mm	Per-km mass, kg	Completed length, m	Type	Dia, mm	Per-km mass, kg	Completed length, m
A-16	5.1	44	6,000	ΠC-25	6.8	194	1,500-3,000
A-25	6.3	68	5,500	ΠMC-25	7.8	296	
A-35	7.5	95	4,500	ΠC-35		396	
A-50	9.0	137	3,500	ΠMC-35	9.2		
A-70	10.6	188	2,500	ΠC-50		11.5	
A-95	12.4	266	2,000	ΠMC-50	12.6		
A-120	14.0	323	1,500	ΠC-70		755	
AC-16	5.4	62	3,000	ΠMC-70			
AC-25	6.6	92	3,000	ΠC-95			
AC-35	8.3	128	4,500	ΠMC-95			
AC-50	9.9	183	3,000	ΠCO-4	4	99	500
AC-70	11.6	296	2,000	ΠCO-5	5	154	240
AC-95	13.9	431	1,400	ΠCO-6	6	222	230
AC-120	15.0	524	1,400				

Notes. 1. The conductor type designation shall be decoded as follows: A – aluminium; AC – steel-core; ΠCO – steel, single; ΠC – standard steel, stranded; ΠMC – copper steel, stranded.
2. The table includes only most widely used conductors for overhead lines of up to 1 kV.

The following operations are included: paying-out of conductors along the line route and jointing them, raising of conductors, sag adjustment, and conductor fixation on insulators.

7.5.1. Conductor Paying-Out and Jointing

Conductors shall be paid out on both ends of the erected pole supports along the line. For paying out from conductor coils, use can be made of conical turntables (Fig. 107a) or portable stands (Fig. 107b); conductors wound on drums can be paid out by means of a collapsible hoist (Fig. 107c).

Where the line is not longer than 0.5 km and the conductor cross-sectional area is not over 50 mm², the turntable, stand, or drum is mounted on the drum

hoist at the first support on the starting end of the line, the conductor end is gripped and run out to the last support, that is, to the finishing end of the line. Where the line is longer, these facilities are mounted on a vehicle with the tailgate flapped open. The conductor is paid out as the vehicle moves along the line from one support to another, taking care to prevent its spinning. As the conductor is paid

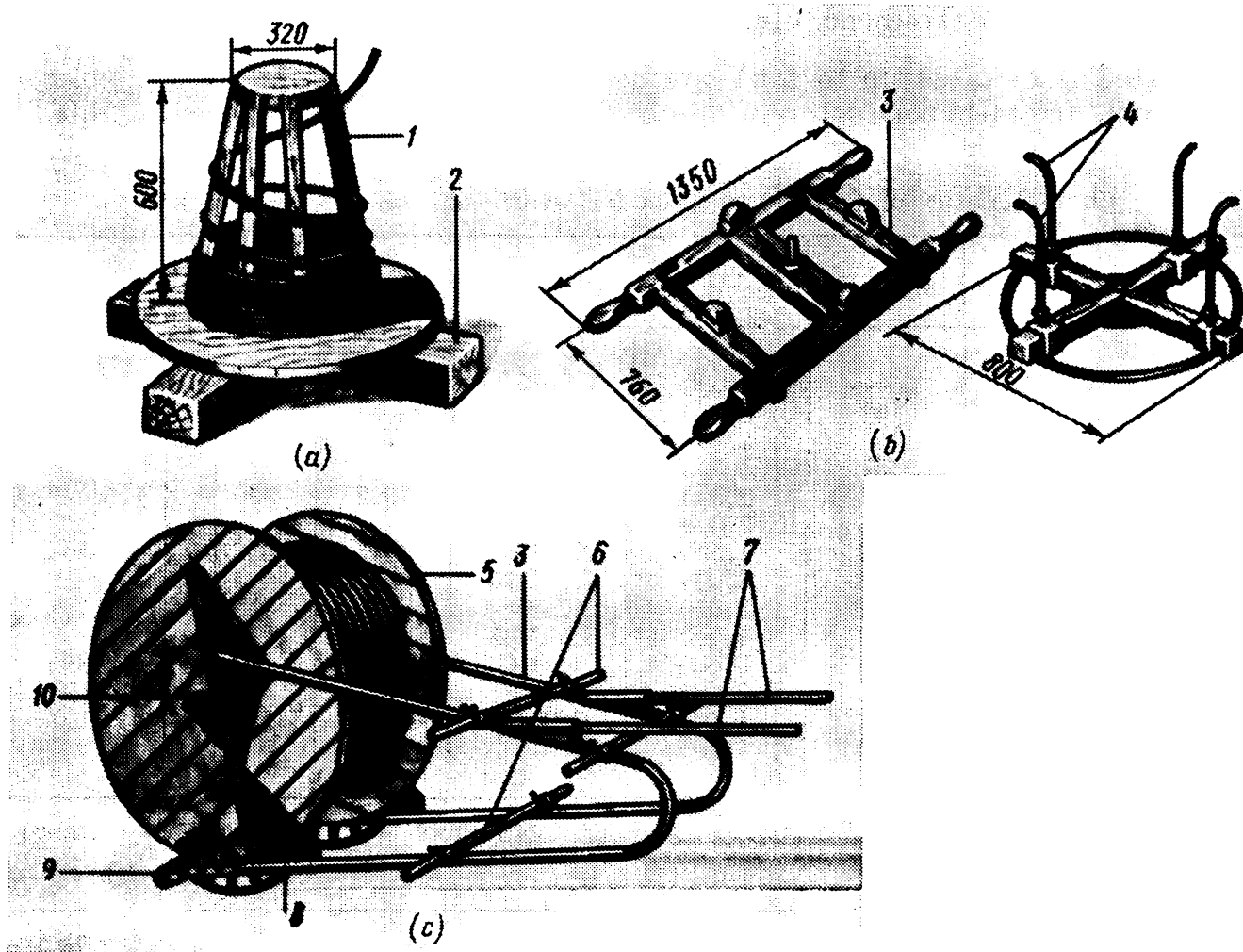


Fig. 107. Conductor paying-out facilities

a—conical wooden turntable; *b*—collapsible stand with metal posts; *c*—collapsible drum hoist; 1—cone; 2—cross-piece; 3—frame; 4—metal posts; 5—drum; 6—rods; 7—grips; 8, 9—side and supporting rollers; 10—drum spindle holder

out, it must be examined for defects, such as broken strands, large dents, and the like. Faulty sections of conductors are marked with paint and repaired before the conductors are raised on supports.

A conductor delivered to the installation site wound on a jack-mounted drum is paid out without being removed from the drum, but the latter shall be raised 10 to 15 cm above the floor of the vehicle body by means of a jack or a pipe inser-

ted in its centre hole. The conductor end is tied to an anchor support wherefrom the procedure is started, then the conductor is paid out as the vehicle moves towards the other supports along the line. If the conductor is insufficiently long, it shall be jointed to another conductor of the same design, type, and cross-sectional area wound on another drum. Conductors for overhead lines of up to 1 kV can be joined together by one of the following methods: splice-and-twisting; fastening with wire bands; jointing in an oval sleeve followed by compression and welding of conductor leads in a loop; butt welding of conductor ends followed by their compression, together with a shunt, in two separate jointing sleeves; butt welding of conductor ends followed by compression, together with an insert, in an oval jointing sleeve; lap jointing followed by compression in a jointing sleeve; jointing of conductors by means of a bolted clamp.

Splice-and-twisting (Fig. 108a) is the simplest method of jointing single steel and bimetallic conductors. Conductors are lapped on a length of 180 to 200 mm, gripped in the middle of the joint with pliers, one conductor is wound on the other on either side of the pliers, the turns being laid close to one another.

Jointing by wire bands (Fig. 108b) is used for single conductors. The conductor ends are bent at right angles and placed one onto the other on a length of 80 to 120 mm depending on the conductor cross-sectional area. Five or six turns of soft zinc-plated wire, dia 1.5 mm, are wound on one of the conductors being joined, then the same wire is wound on the entire joint. After that another five or six turns of this wire are wound on the other conductor. To render the copper wire stronger at the joint on long spans, the wire band is run over with solder ПOC-30 or ПOC-40.

Joints in an oval sleeve (Fig. 108c) are used for stranded aluminium conductors. Conductors are inserted in an oval sleeve selected to suit the conductor cross-sectional area and pushed towards one another until they emerge from the opposite ends of the sleeve. The sleeve is compressed and the conductor leads are butt-welded* in a loop.

Compression in two sleeves together with a shunt (Fig. 108d) is mainly used for stranded aluminium conductors of 70 mm² and larger cross-sectional areas. The sleeves are compressed by special presses.

Jointing of butt-welded conductors in an oval sleeve followed by compression of the sleeve and conductors together with an insert (Fig. 108e) is most often employed in the middle of a long span for stranded conductors of an overhead line routed over ice regions III or IV where heavy wind pressures on conductors may be expected.

Lap jointing in an oval sleeve (Fig. 108f) is the most simple method used for stranded conductors of 16 to 50 mm² cross-sectional areas.

Methods illustrated by Fig. 108a, b, c, d, e, f can be employed to make joints on conductors in the line spans.

Sleeves must be made of the same material as conductors to be joined in them. So, the type COM copper sleeves are meant for copper conductors, the type COA

* For the conductor compression and welding techniques, fixtures, tools, and presses required, refer to Section 6.4.

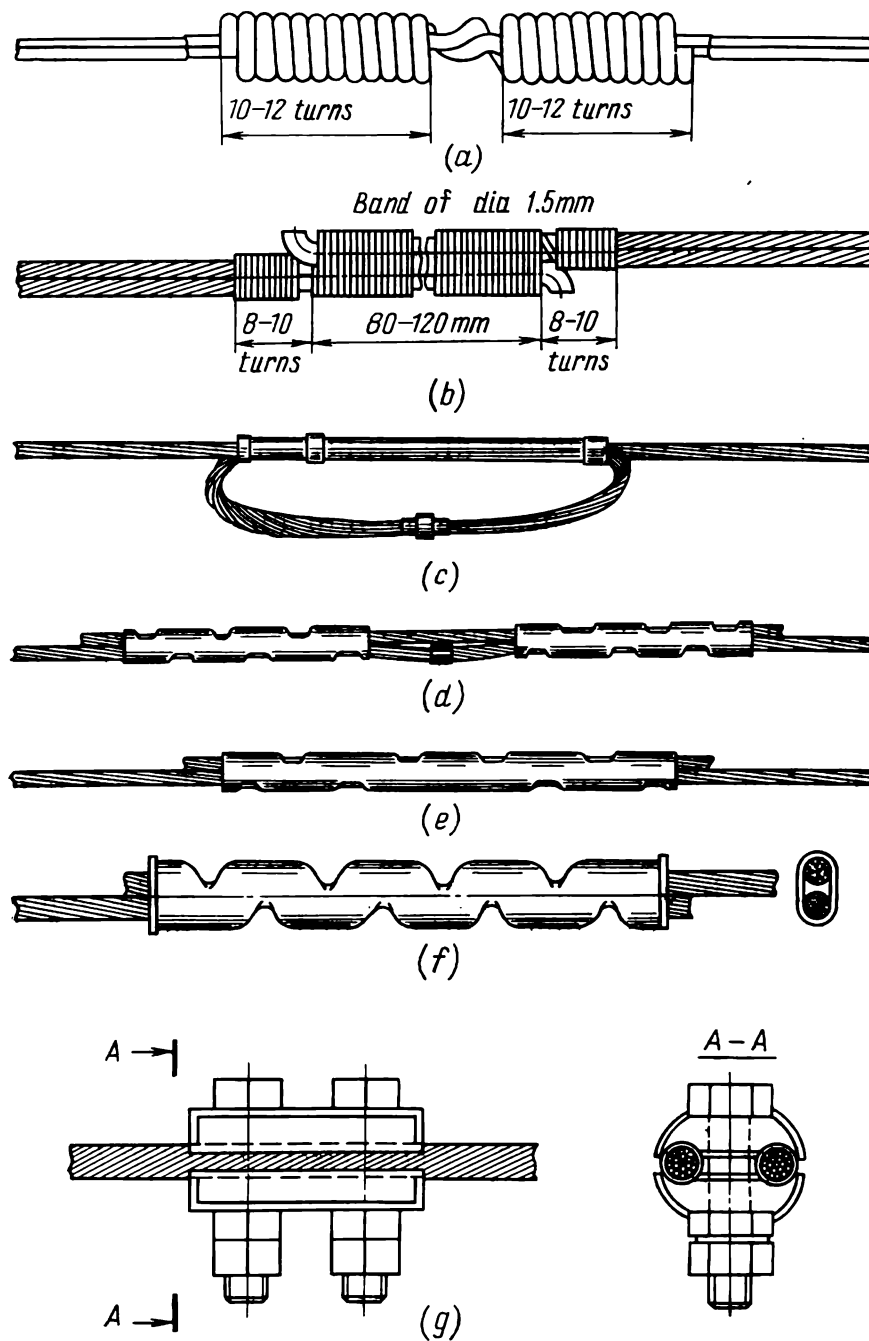


Fig. 108. Jointing conductors of overhead line of up to 1 kV

a—by splicing and twisting; *b*—by wire bands; *c*—by compressing in a sleeve and welding the leads in a loop; *d*—by compressing the conductor together with a shunt; *e*—by butt-welding and compressing in a sleeve; *f*—by lap compressing in a sleeve; *g*—by means of a bolted clamp

aluminium sleeves for aluminium conductors, and the type COC steel sleeves for steel conductors.

Bare stranded conductors can also be joined together by bolted clamps.

A *bolted clamp joint* (Fig. 108g) may be used only for conductors installed on supports provided that the joint will not suffer mechanical loads. The bolted clamp consists of two or three zinc-plated bolts (depending on conductor cross-sectional area), nuts, and two dieplates with longitudinal slots. To ensure the desired contact in the clamp, holes formed as the dieplates are brought together shall be slightly smaller in diameter than the conductors.

Just before mounting a clamp, the contacting surfaces of its dieplates must be flushed in petrol and a thin coat of petroleum jelly must be applied to them. The surfaces of clamps used for jointing aluminium conductors are cleaned off with a steel brush through a petroleum jelly coat. The conductor surfaces to be joined together are to be treated in the same way. The bolts shall be tightened up by means of a wrench, applying a pressure not over 25 kgf. To avoid indentation of conductors being joined together and stripping of the bolt thread, no tools shall be employed for tightening up the bolts at a greater force.

The threaded portions of the bolts and nuts must be coated with petroleum jelly or solid oil. Lock-nuts must not be omitted. After the bolts are tightened up, a clearance of 3 to 5 mm must be provided between the dieplates. A tight fit between the dieplates is the indication of a poor contact. When this is the case, the clamp must be replaced by a new one. To prevent oxidation of contacting surfaces, the latter are smeared at outer clearances and at the points where the conductors leave the clamp with a paste composed of lead minium diluted in natural drying oil. The coat thickness is to be 1 to 3 mm.

The clamp bolts shall be additionally tightened up 8 to 10 days after installation because the pressure between the dieplates and the conductors will decrease as a result of the reduction in the conductor elasticity. If this measure is not taken, there may be a poor contact between them and undesirable heating of the joint.

In running out overhead line conductors, it may be required to cross railways, heavy traffic roads, or communication lines whose operation must not be interfered with even for a short period of time. In such events use shall be made of auxiliary derricks or ladders, or some other facilities.

When paying out conductors in close proximity to live overhead lines, trolley lines, electrified transport, and outdoor substations, measures shall be taken to prevent accidental contact with current-carrying parts of these electrical installations.

7.5.2. Conductor Lifting, Sag Adjustment, and Attachment to Insulators

Conductors run out along the line route are lifted by means of poles and thrown on the hooks of pole supports. In order to prevent confusion of conductors, first one (the uppermost) conductor is better to be lifted and strung, then the remaining conductors, one after another.

In suspending conductors from supports, they shall be arranged in an appropriate order. This requirement is dictated by the fact that at ambient temperature fluctuations the sag of conductors made of different materials changes differently. Aluminium conductors are most responsive to temperature fluctuations between the minimum and the maximum values, and steel conductors elongate the least with temperature. Therefore, under most adverse conditions, for example, at ambient temperatures approaching minus 40°C, aluminium conductors must not be placed below copper or steel conductors in a span, otherwise they may approach too close and even come in contact.

In order to maintain specified spacings between conductors arranged vertically on a support and made of different materials, the aluminium conductor must be placed above all the other conductors, and the steel conductor below all of them.

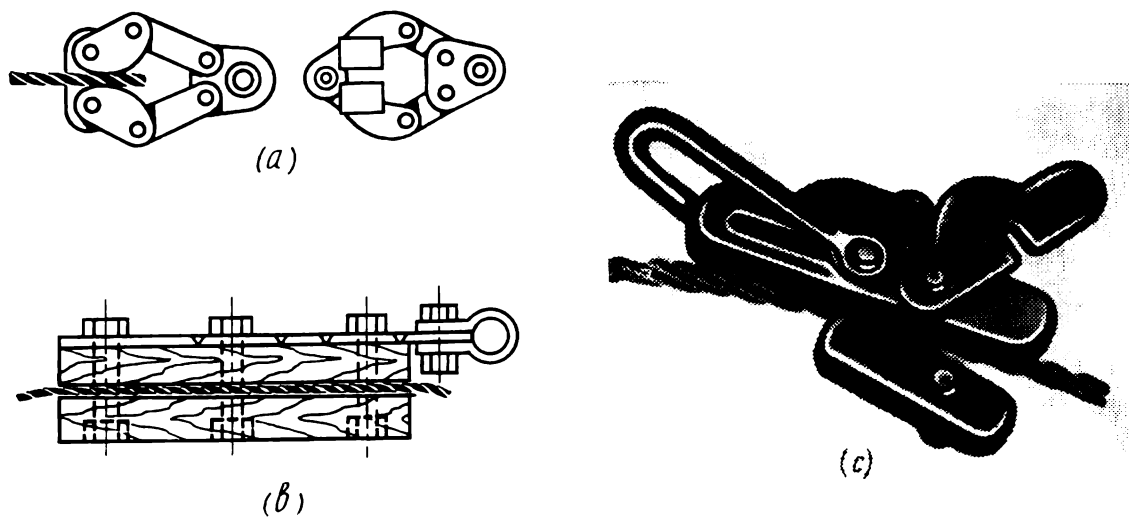


Fig. 109. Facilities for conductor installation

a—grip with round and flat clamps; *b*—comealong clamp; *c*—universal comealong clamp K9C-70

Where conductors made of the same material (for instance, only aluminium or only steel conductors) are arranged in vertical configuration, their arrangement is arbitrary because their sag at any variations in ambient temperature will change to the same degree.

Conductors are tensioned separately in every anchor span, that is, in every span between anchor supports, including angle and dead-end supports. One end of the conductor is made fast to the insulators of a dead-end or anchor support in a dead loop and the other end is held by a grip (Fig. 109*a*) or by a special comealong clamp (Fig. 109*b*) having grooves to receive conductors of different sectional areas. A grip with flat clamps is most suitable for copper and, especially, for aluminium conductors of large sectional areas, because in round clamps the conductor may get damaged while being tensioned. The best of all is a universal comealong clamp illustrated by Fig. 109*c*. A pulley block is attached to the grip or clamp, and the conductor is tensioned by taking up the pulley block rope till the desired sag is obtained. When installed in long spans, conductors of a cross-sectional area lar-

ger than 50 mm² are tensioned by means of a hand-operated or motor-driven winch.

An equal sag must be ensured for all the conductors within the same anchor span. When conductors of different cross-sectional areas are suspended, the sag is determined by the conductor having the largest area. The conductor sag is found from sag curves or charts for actual ambient temperatures. Due consideration is given to the rated ambient temperature t_1 and original temperature t_2 (at $\varphi_{\max} = \varphi_1$, $t_2 = -40^\circ\text{C}$ and at $\varphi_{\max} = \varphi_2$, $t_2 = -5^\circ\text{C}$). The conductor sag is calculated as follows. The ruling span (l_r) and the maximum sag (f_{\max}) are taken as given, the maximum strain of conductor (σ_{\max}) and the strains (σ_t) as functions of ambient temperature varying within the installation period are calculated, and then the desired sag (in metres) is found from the equation

$$f_t = \frac{l_r^2 \varphi_1}{8\sigma_t}$$

Approximate sags for aluminium conductors of overhead lines of up to 1 kV are given in Table 40.

Table 40

Sags for Aluminium Conductors of Overhead Lines of Up to 1 kV

Span length, m	Sag, cm						
	conductor sectional area, mm ² , at +10° C					All sectional areas	
	up to 25	35	50	70	95	at +25° C greater by, cm	at -10° C smaller by, cm
30	40	50	60	80	90	8	15
40	50	60	70	80	100	10	20
50	70	70	90	100	120	15	25

Note. The above-specified sags are valid for line conductors spaced at least 400 mm apart.

The desired sags can be obtained by different methods, the most simple and, hence, most popular being direct sighting.

In order to obtain the desired sag, a graduated batten is attached to each of the two adjacent supports, and then a lineman climbs one of the supports and gives the signal to tension the conductor till its lower point gets in alignment with the sighting point (Fig. 110).

With the conductors arranged in vertical configuration, the sag adjustment is started from the upper conductor, and with those arranged in horizontal configuration from the middle conductor. After the desired sag is achieved the conductor is fastened with a binding wire to insulators. The binding wire must be of the same material as the conductor.

Steel conductors are tied with zinc-plated steel wire, dia 1.5 to 2 mm, and aluminium conductors with aluminium wire, dia 2.5 to 3.5 mm. Strands of stranded conductors can also be used.

At the points of attachment, aluminium and steel-core aluminium conductors are wrapped in aluminium bands before being tied up to prevent damage.

On suspension supports conductors are primarily attached to the insulator heads, and on angle supports to the insulator grooves, with the insulator being

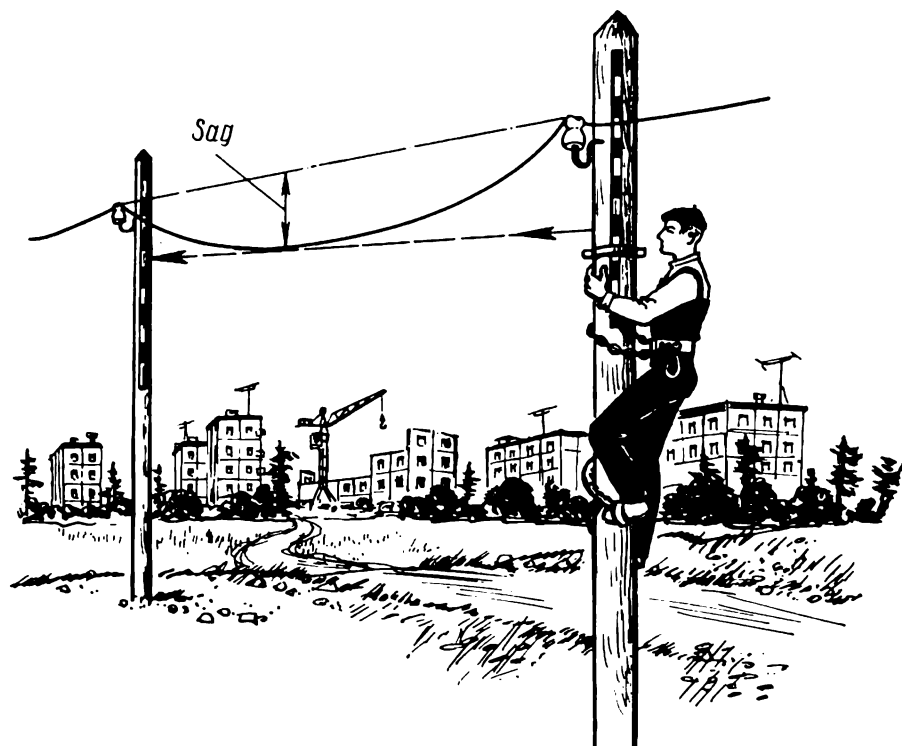


Fig. 110. Determination of conductor sag

arranged on the outside of the angle formed by conductors. Conductors are secured to the insulator head with two lengths of binding wire (Fig. 111*a*). The wire is tied around the head so that its different-length leads are arranged on both ends of the groove, then two short leads are wound in four or five turns around the conductor and two long leads are passed over the head and also wound in a few turns around the conductor.

For securing the conductor to the insulator head (Fig. 111*b*), the binding wire is looped over the insulator head and groove, then one of its ends is wound on the conductor in one direction (from top downwards), and the other end in the opposite direction (from bottom upwards).

On anchor and dead-end supports conductors are secured by means of an end cap to the insulator groove (Fig. 111*c*). Where the overhead line crosses railways and tramways, or other overhead power lines and communication lines, the conductors are double fastened as is illustrated by Fig. 111*d*.

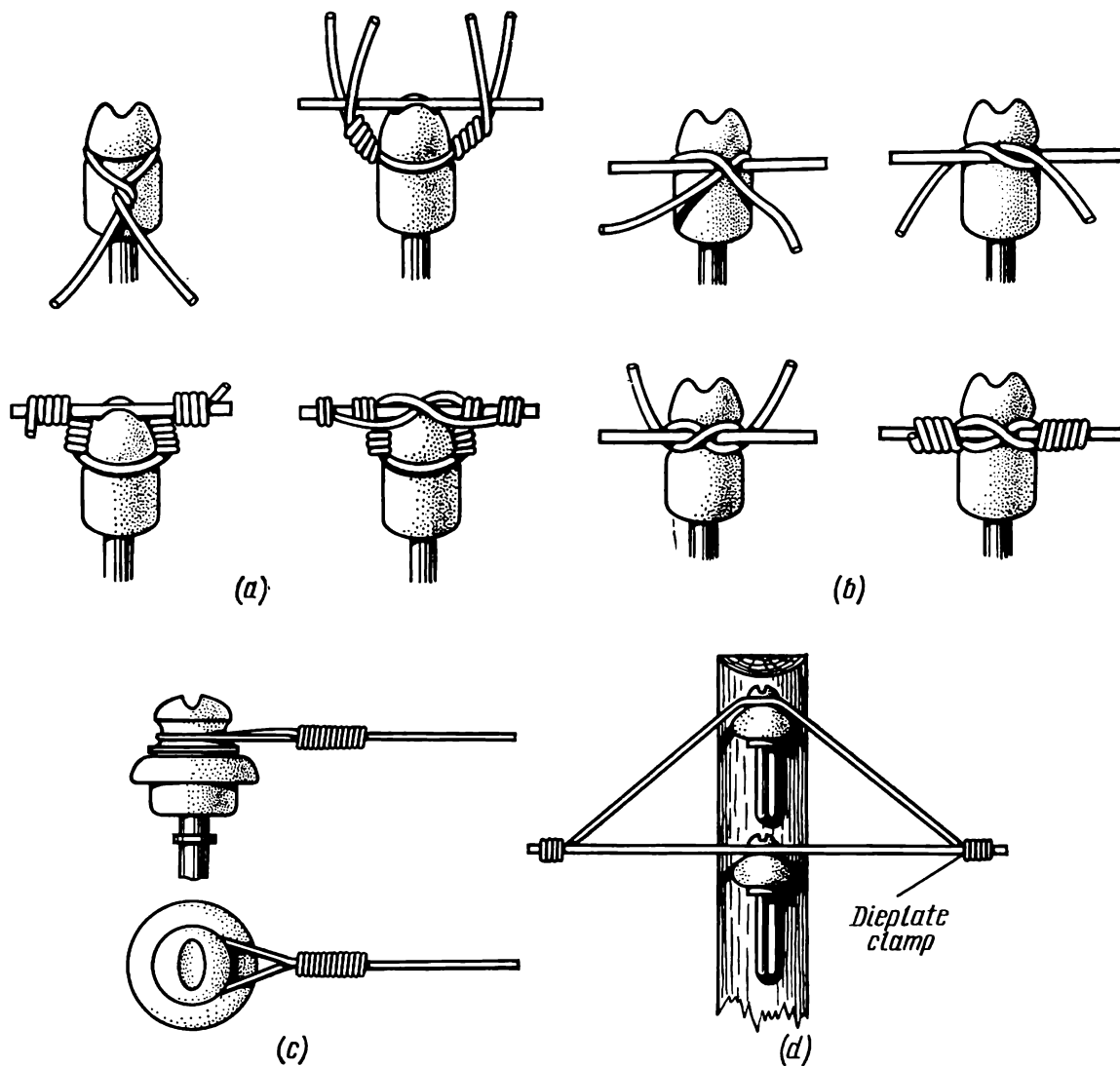


Fig. 111. Attachment of line conductors of up to 1 kV to insulators

a—by tying to the head; *b*—by tying to the groove; *c*—by means of a dead loop; *d*—by a double attachment

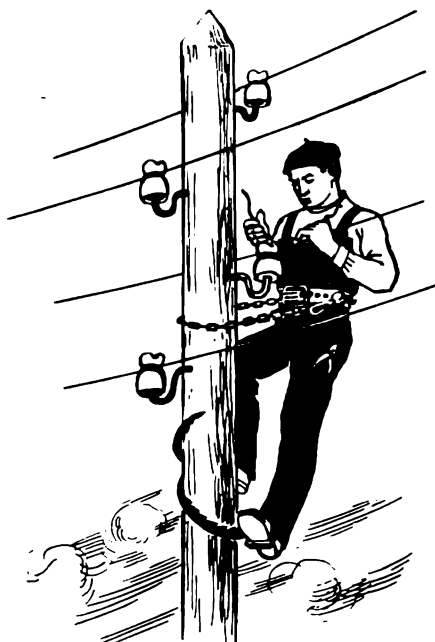


Fig. 112. Correct position of a lineman on a pole-support for fixing conductors on it

The lineman performing these operations must wear a cap, reliably secure himself to the pole with climbers and with the chain of his safety belt (Fig. 112). Linemen shall never be allowed to work on angle supports inside of the turn-angles of change in the direction of the line.

The metalwork of ferroconcrete supports for overhead lines of up to 1,000 V with an earthed neutral must be reliably connected to the neutral wire.

After the line is erected, all its supports shall be marked with numerals indicating the line number, the support sequence number and the year in which the particular support is erected. Numerals are applied with black paint at a height of 3 or 4 m on the most-easy-to-observe side.

A newly erected overhead line must be commissioned. Those who accept the overhead line must examine all its elements (from the ground); the crossarms, braces, stub poles, insulators and conductors must be checked for reliable fastening (from the top); the supports must be examined (at random, but not less than 10 per cent of supports) for the depth through which they are buried in the ground. Conductors shall be checked for sags, minimum clearance between the low point of the sag and the ground and for safety clearances of conductors at points where they approach or cross terrain objects.

Review Questions

1. How and on what basis are overhead lines classed?
2. What structural elements of pole supports do you know?
3. What methods are used for laying out an overhead line route and a hole for an anchor supports?
4. How are pole supports raised and erected?
5. How is conductor sag determined and adjusted?
6. How are overhead line conductors attached to insulators?

Installation of Power Equipment Rated up to 1 kV

Electrical equipment includes miscellaneous current conducting systems, electric motors, circuit-opening devices, switchgear and control gear that are distinguished by the current system, rated voltage, mechanical design, and technical characteristics.

Pieces of electrical equipment most widely used in industrial plants are busways, electric motors, starting and control gear.

8.1. Installation of Busways

8.1.1. General

A busway or busbar arrangement functions to conduct electric current. It consists of differently shaped busbars, insulating parts, and supporting structures.

According to enclosure, the busways are grouped into open, protected, enclosed, splash-proof, and dust-tight. Open and protected busways are fabricated by local preassembly divisions, while enclosed, splash-proof, and dust-tight arrangements are supplied by special factories reporting to large installation boards.

In the installation of busways intended to carry currents exceeding 1,500 A the following shall be borne in mind:

(a) separate parts of metalwork and busways shall be made of non-magnetic materials or an air gap shall be provided on the path of the magnetic flux to reduce power loss in busbar holders, accessories, and supporting metalwork;

(b) separate sections of busbar casings shall be isolated and each section shall be earthed at one point of the pole support only and insulated from metalwork at the remaining fastening points so as to exclude closed loops when earthing the casings of enclosed busways.

Where busways cross expansion joints of building components or pass over sections subject to serious mechanical strain (due to temperature fluctuations, heavy vibrations, etc.), expansion devices shall be used at crossings and transfer sections.

Non-split joints of busbars within a busbar section shall be better made by welding.

Building components mounting busways must be made of robust non-combustible materials. Special ports or insulating boards shall be provided to pass the busbars through walls, floors and ceilings.

Where an open busway is brought out through a floor or ceiling, its current-carrying parts mounted on a wall must be placed in a totally enclosed duct at a height of at least 3.5 m; the busduct must be reliably earthed. In industrial premises accessible to unauthorized personnel specified clearances between the busbars and the finished floor surfaces are minimum 3.5 and 2.5 m for open indoor and protected busways, respectively. For enclosed busways these clearances are not specified. The distance from open busbars mounted indoors to the nearest pipelines shall be minimum 1 m, and to the technological equipment minimum 1.5 m. For enclosed busbars these distances are not specified.

8.1.2. Installation of Open Busways

An open busway is an arrangement built up of steel, aluminium, and copper busbars of a rectangular, square, or tubular section, secured by means of bolts and clevises to bracket-mounted insulators; they also include racks or some other supporting structures.

Busbar supporting structures are attached to building components or elements (walls, ceilings, trusses, columns).

The installation procedure is started from marking out the busway route. Stages, scaffolds, telescopic towers are required for this. Marking-out is made by means of a steel measuring tape and templates. The busways must be routed away from industrial shop utilities, such as pipelines, ventilation ducts, and the like, because it is a hard problem to by-pass these obstacles.

Supporting structures for busbars shall be equally elevated from the floor and equally spaced apart. The spacings are specified by the project.

Insulators are mounted on supporting structures before the latter are secured to walls, trusses, or columns.

Rectangular aluminium busbars measuring 100×10 mm are cut by means of special shears. Aluminium busbars of large sectional areas or of a shaped section are cut by means of bus-cutting machines or a standard fitter's hack saw.

Rectangular-section busbars up to 60 mm wide and those 80 mm and wider still are lap-jointed by two and four bolts, respectively. The busbar ends to be bolted together are machined in advance under a layer of petroleum jelly on a busmilling tool or filed off with a bastard file to ensure reliable contact of the joint. Spring washers are fitted under the bolt heads and nuts.

Bolted joints of aluminium conductors are insufficiently reliable. In the course of operation separate sections of the busway heat up to such an extent that the joint wants repair. Welded joints are more reliable in this respect. Busbars are joined by d.c. or a.c. arc welding or by argon-arc welding. Figure 113*a, b, c* illustrates welded joints of rectangular-, square-, and tubular-section busbars. Special fixtures are usually employed in welding. Where conditions allow, however, they can be welded up upon being mounted on supporting structures.

Aluminium busbars for busways shall be minimum 120 mm^2 in cross-sectional area and 5 mm wide. Light-mass busways with aluminium busbars measuring maximum 40×5 mm are preassembled at preassembly division workshops and supplied complete with all the electrically welded taps, supporting structures,

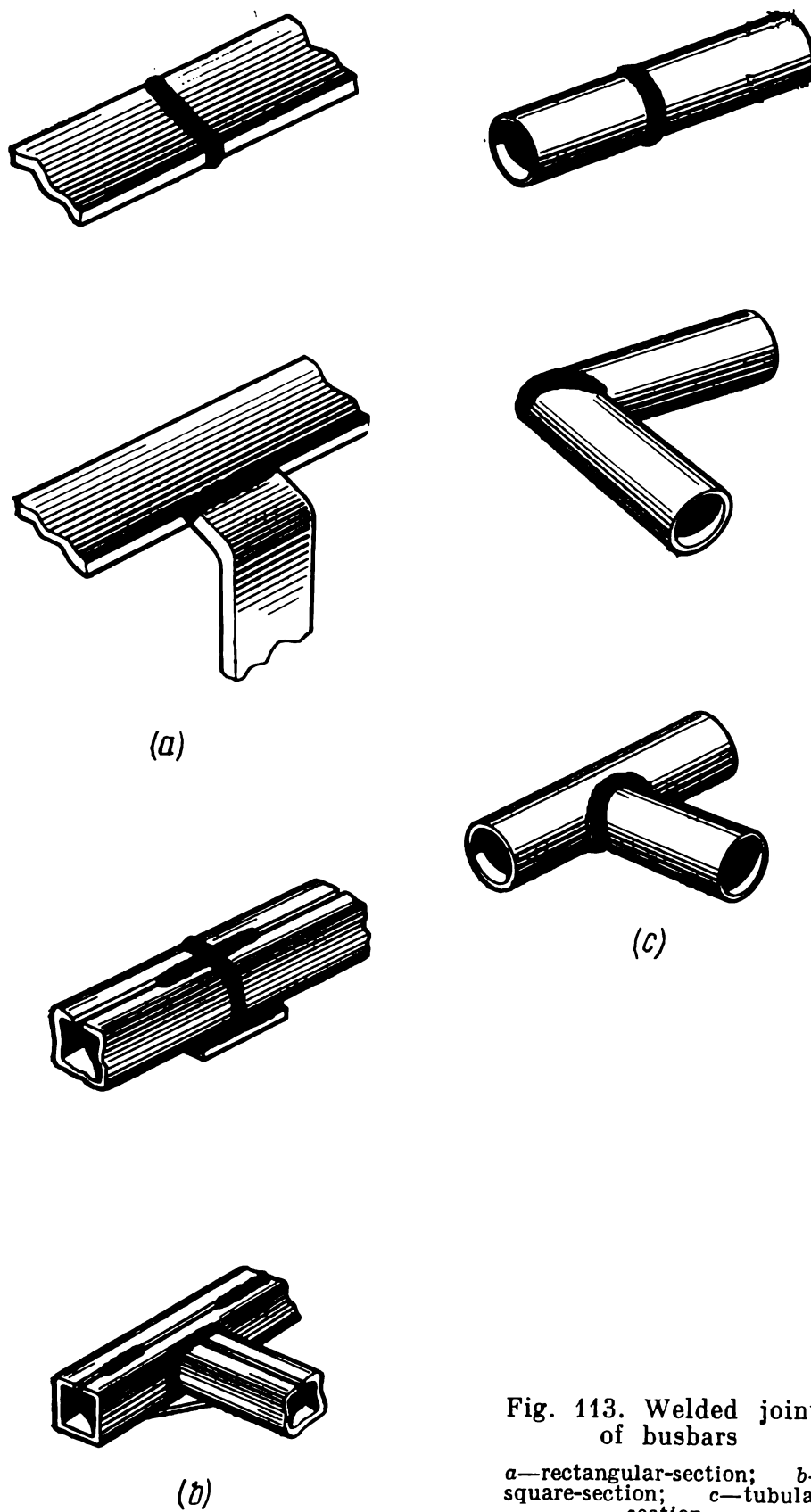


Fig. 113. Welded joints of busbars

a—rectangular-section; *b*—square-section; *c*—tubular-section

insulating parts, strain facilities, sectionalizing circuit-opening devices, etc. Each set of busbars is marked as to phase and is wound on special fixtures into coils of about 2 m in diameter to be delivered on site.

To install busways, the following operations shall be carried out. Painted metal structures are mounted on building components or elements strictly at the same level accurate to ± 5 mm in the horizontal plane and to ± 3 mm in the vertical plane. The busbar assembly is run out on the floor, one phase after another, each is then partly straightened up, and welded joints are checked for condition. Supporting structures and brackets for strain facilities are set in position, and snatch blocks receiving the winch rope are mounted on the extreme trusses. The busbar of one phase is tied to the winch rope end, raised by means of the winch, and pulled through the snatch blocks from one extreme truss to the other. The remaining busbars are installed in the same manner; the one being closest to the building wall is the first to be mounted.

Protected busways are mounted almost by the same method as open arrangements, the only difference being that they are furnished with removable metal screens or light-mass ducts.

More advanced in design, though more complicated to install, are busways composed of prefabricated elements.

8.1.3. Installation of Enclosed Busways

Enclosed busways are metalclad arrangements enclosed in fixed ducts. They are used as main and distribution current conducting facilities supplying power to various pieces of electrical equipment installed in industrial shops.

The series IIIMA main-line aluminium busway sections are used for main-line busways, and the series IIIPA distribution aluminium busbar sections for tap-off or distribution busways.

The main-line busways of the IIIMA series (Fig. 114) for a.c. industrial electrical equipment are available in the following basic types: IIIMA, for electrical equipment operating under normal conditions; IIIMAX, for electrical equipment operating in chemically active atmospheres.

The series IIIMA busways are made in the form of straight sections (Fig. 114a), straight adjustable sections (Fig. 114b), tee-way sections (Fig. 114c), and corner sections (Fig. 114d). Current is supplied to the main-line busways through a busbar sections incorporating a lead-in box (Fig. 114e).

The series IIIMA busways for large working currents of 2,500 and 4,000 A are made with twin busbars per pole per phase (Fig. 114f). The type KO-IIIMA branch boxes (Fig. 114g) are used to make tap-offs from the main-line busbar sections. The busbars of these boxes are welded on one end to the main-line busbars and connected on the other end to the equipment busbars or cables.

The busbars in the IIIMA busways are set on edge to facilitate their jointing and to improve cooling conditions. Each section of the busway consists of three, four, or six (three twin) aluminium busbars insulated with glass fabric ЛСЭ.

In the course of operation the busbars run hot as they pass working currents, which may cause the destruction of welded joints or insulating parts, and short

circuits due to excessive sagging of elongated busbars resulting in too short clearances between adjacent busbars of different phases, unless expansion devices are installed.

Expansion devices are fitted in straight adjustable sections to compensate for the elongation of busbars due to high temperatures.

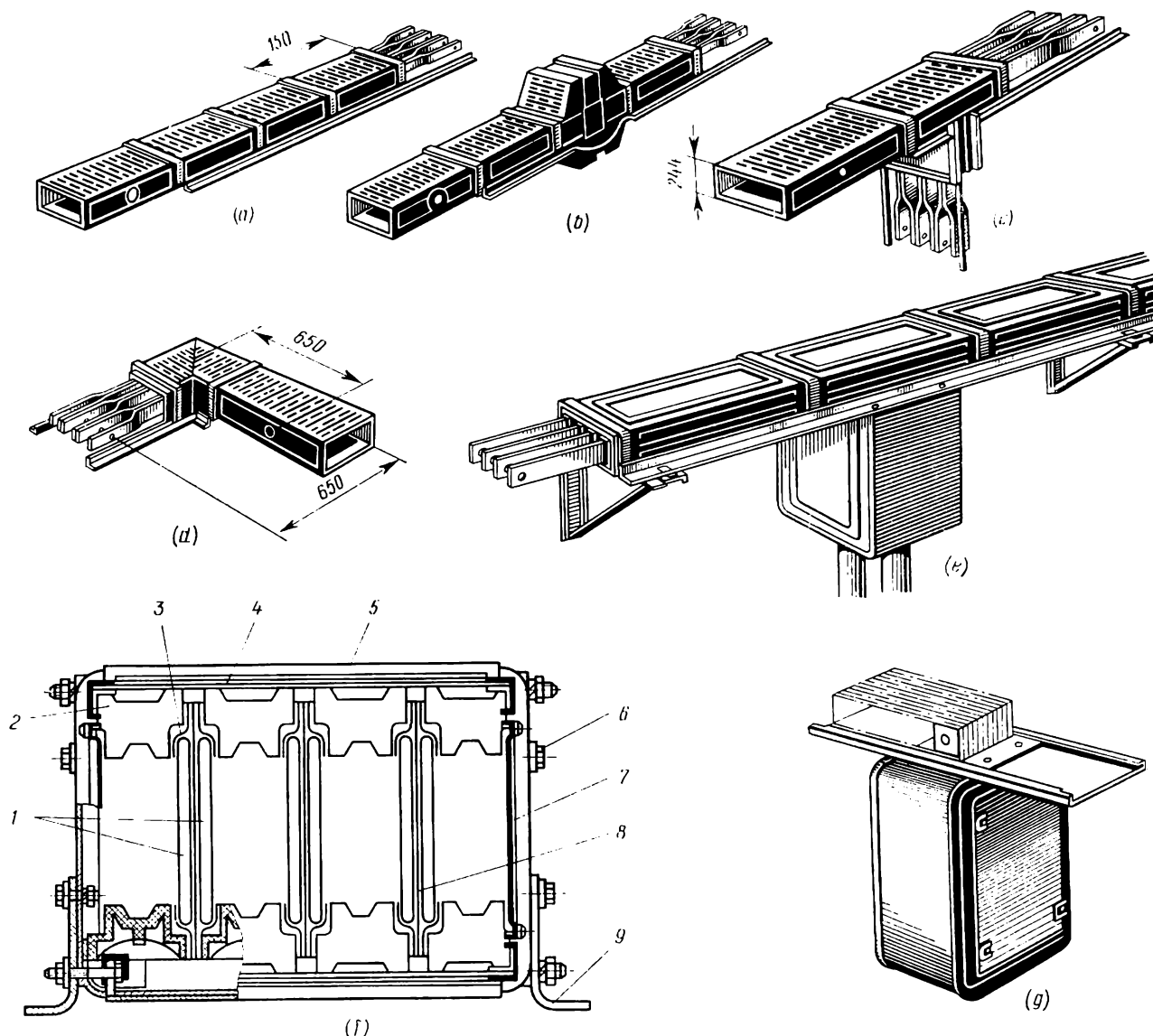


Fig. 114. Sections of main-line busways IIIA

a—straight section, 3 m long; *b*—straight adjustable-length section; *c*—tee-way section; *d*—corner section; *e*—straight section with a lead-in box; *f*—sectional view of a section with twin busbars; *g*—section with a branch box; 1—busbars of one phase; 2—insulator; 3—elastic spacer; 4—upper cover; 5—holder; 6—earthing bolt; 7—side cover; 8—insulating barrier between busbars; 9—angle piece for fastening the busway to a supporting structure

Power distribution to separate pieces of electrical equipment installed in industrial premises is afforded by the type IIIA distribution busways composed of bare busbars measuring 30×4 , 50×5 , or 60×6 mm (for currents of 250, 400, or 600 A, respectively) set on edge in special porcelain insulators fixed within

a busduct. Distribution busbars are loosely fitted in insulators and are free to move along the busduct as they change their length due to temperature variations. These busbars are provided with plug connectors for the connection of outgoing lines. Hence, another name of these busbars is plug-in busbars.

Busbars can be installed horizontally or vertically.

Prior to installing a busway, each section shall be checked for missing standard items and for condition. Building components and supporting structures shall be checked for readiness to receive them.

Busways are usually installed in two stages. The first stage includes marking-out of positions of supporting structures, installation of supporting structures on

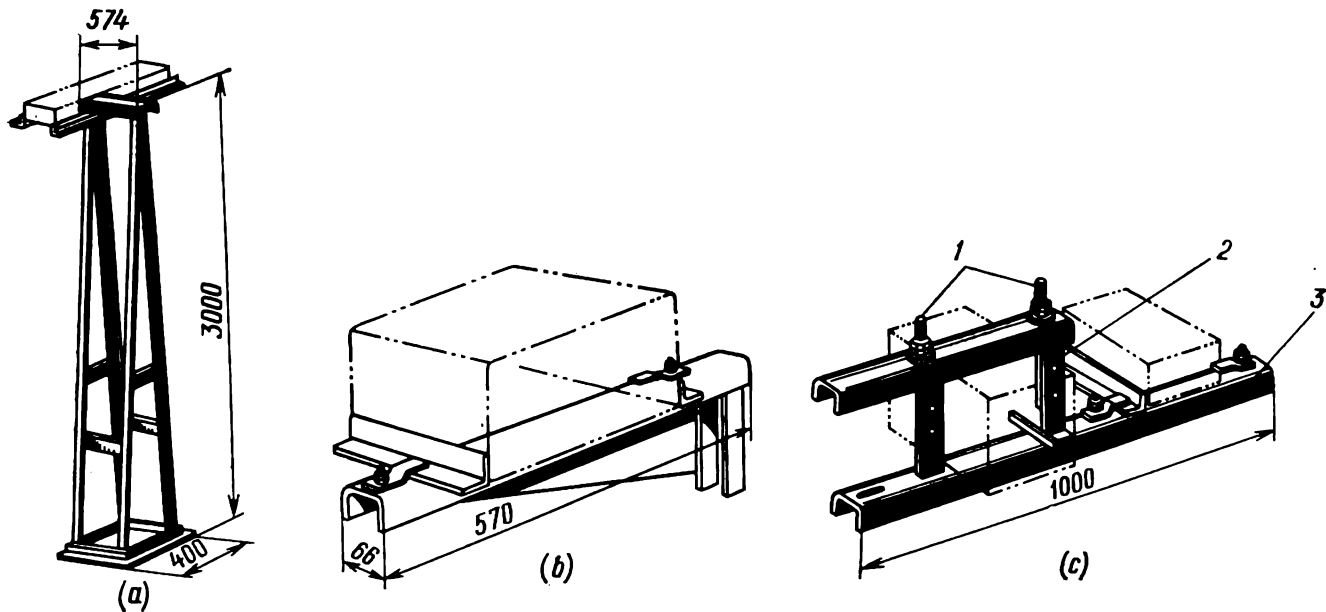


Fig. 115. Supporting structures for main-line busways II MA

a - floor-mounted rack K882; *b* - wall-mounted bracket K881; *c* - bracket K883 for the attachment of busway to a ferroconcrete truss; 1 - clamping studs; 2 - adjustable struts; 3 - bracket yoke

walls, columns, etc., and laying of wiring pipelines. During the second stage the busbars are attached to the supporting structures and connected to supply and outgoing lines.

Busbars are held on walls, columns, ferroconcrete or metal trusses by means of brackets or on racks.

Most convenient for the installation and maintenance of busbars are the type K882 racks (Fig. 115*a*) of a standard height of 3 m to be spaced at least 3 m apart. The sectionalizing switch, if incorporated in the main-line busway, shall be mounted on the rack so that the centre line of its handwheel is brought in coincidence with that of the rack. Sections incorporating expansion devices must be mounted at a minimum distance from the rack (not longer than 1,200 mm).

The type K881 stamped brackets (Fig. 115*b*) are used for horizontal mounting of busbars on walls and columns. The supports of these brackets are secured to the walls or columns so that the brackets proper are set horizontally.

Where busbars are to be installed on walls having protruding columns, standard brackets are mounted on the latter, and extensible brackets are installed on the walls so that their overhang can be extended as required.

Where ferroconcrete trusses are arranged indoors, busways are routed over the lower chord on the type K883 collapsible brackets (Fig. 115c). The bottom yoke of the bracket meant to support the busway sections is secured to the ferroconcrete truss through struts and clamping studs.

Brackets with welded-on lugs are employed for the vertical installation of busways on walls. The brackets are fixed with dowels driven in by piston gun ПИ52-1 or gun ЦМН-3М. Busway sections are installed on supporting brackets and bolted in position. Holes for bolts are drilled in the brackets and in the flanges of the busducts in advance.

One of the popular methods of main-line busway installation is suspension from a catenary cable provided with guy. This method offers simple installation and routing of busways outside of the working areas of industrial premises. Where the main-line busway is routed along columns, a combination method of fixation is used, that is, brackets are installed on columns and catenary hangers are strung between the columns. Busbar sections are secured on catenary hangers spaced 3 m apart.

Whatever method of installation is used, busbar sections are joined together with the aid of single-bolt couplers (Fig. 116a, b). Busbars shall be joined so that their holes are aligned. These holes receive an insulating tube 11, whereon plastic disk insulators are fitted. Then a clamping stud 3 is inserted in the tube, aluminium washers 8, steel washers 9, and a disk spring 10 are installed on it, whereupon the joint is tightened up with a nut turned onto the stud.

Single-bolt couplers are supplied by the manufacturers in a limited quantity sufficient for jointing not more than 30 or 35 per cent of busbars. Therefore, most joints of the busways shall be made by welding. Prior to welding, aluminium busbars must be wiped with a petrol-moistened rag and thoroughly cleaned off with a steel wire brush to remove oxide film from the surfaces to be joined together. This done, the busbars are placed in a special jig, their edges are coated with a thin layer of the АФ-4А flux, and then the welding procedure is started. Welding is made with a carbon electrode which serves for a simultaneous fusion of both the edges. An aluminium welding rod is moved ahead of the arc and the molten metal of the busbars is permanently stirred by this rod. The welding rods are smeared with a compound composed of 65 per cent flux АФ-4А and 35 per cent cryolite.

After its cooling, the welded joint is cleaned off with a wire brush, degreased by wiping it with a rag moistened with acetone, and then insulated with epoxy compound K-115 applied in a coat not less than 0.5 mm thick. The compound is applied with a brush in two layers, the second layer being applied at least 8 hours after the first one. Epoxy compound must fully cover the exposed sections of the busbars and, besides, the glass fabric insulation over a length of at least 10 mm so as to make the entire busway equally reliable in respect to electric strength. Insulating procedures shall be carried out at an ambient temperature of not lower than 5°C.

The installed busways are checked for tightness of supporting structures and bolts at bolted joints of busbars, strength of welded joints, condition of insulating coats on the busbars and their joints. Then the busbar insulation is tested.

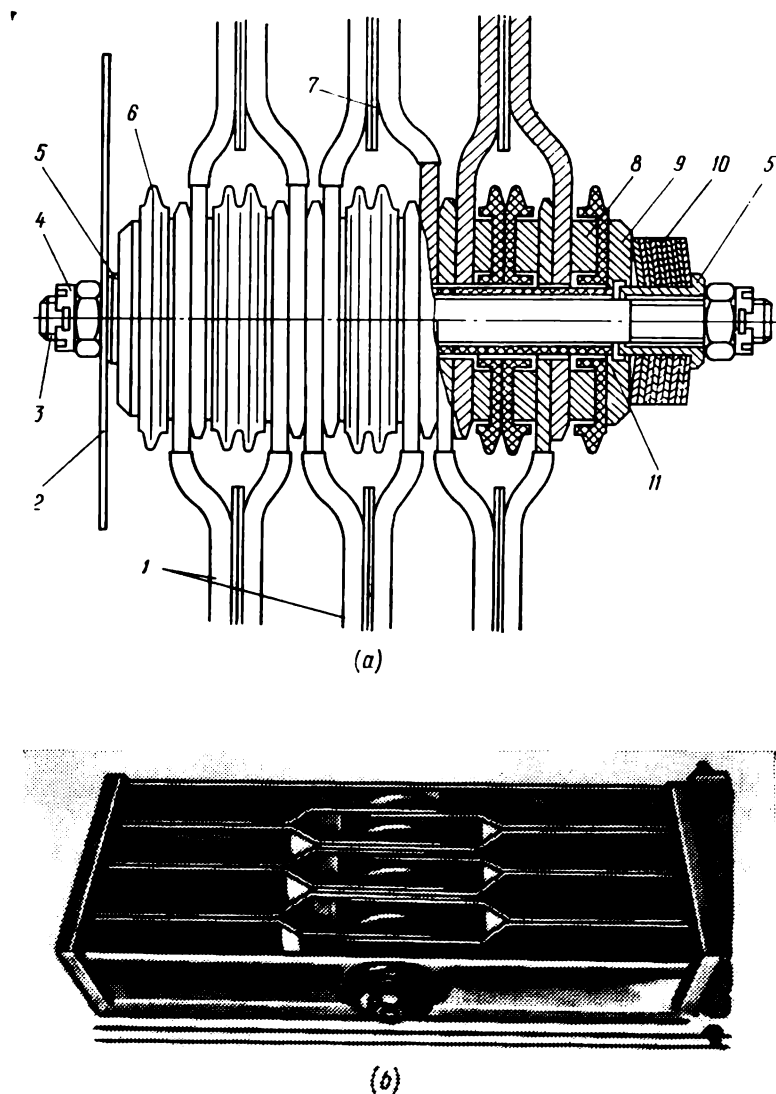


Fig. 116. Sections of a IIIMA busway joined together with a single-bolt coupler (ferrule)
a—sectional view; *b*—general view; 1—current-carrying busbars; 2—earthing busbar; 3—clamping stud; 4—cotter pin; 5—insulating bushes; 6—disk insulators; 7—interbar spacer; 8—aluminium washer; 9—steel washer; 10—compressive disk spring; 11—insulating tube

The minimum insulation resistance of busbars, as specified by the Regulations for Electrical Installations, is $0.5\text{M}\Omega$, as measured with a 2,500-V megger*.

Before testing the busway insulation, the branch boxes must be removed and the circuit breakers of lead-in boxes must be disconnected, because these elements

* The insulation can likewise be tested by applying a test voltage of 1,000 V a.c. for 1 minute.

of busways are tested in compliance with different standards during the early adjustment period.

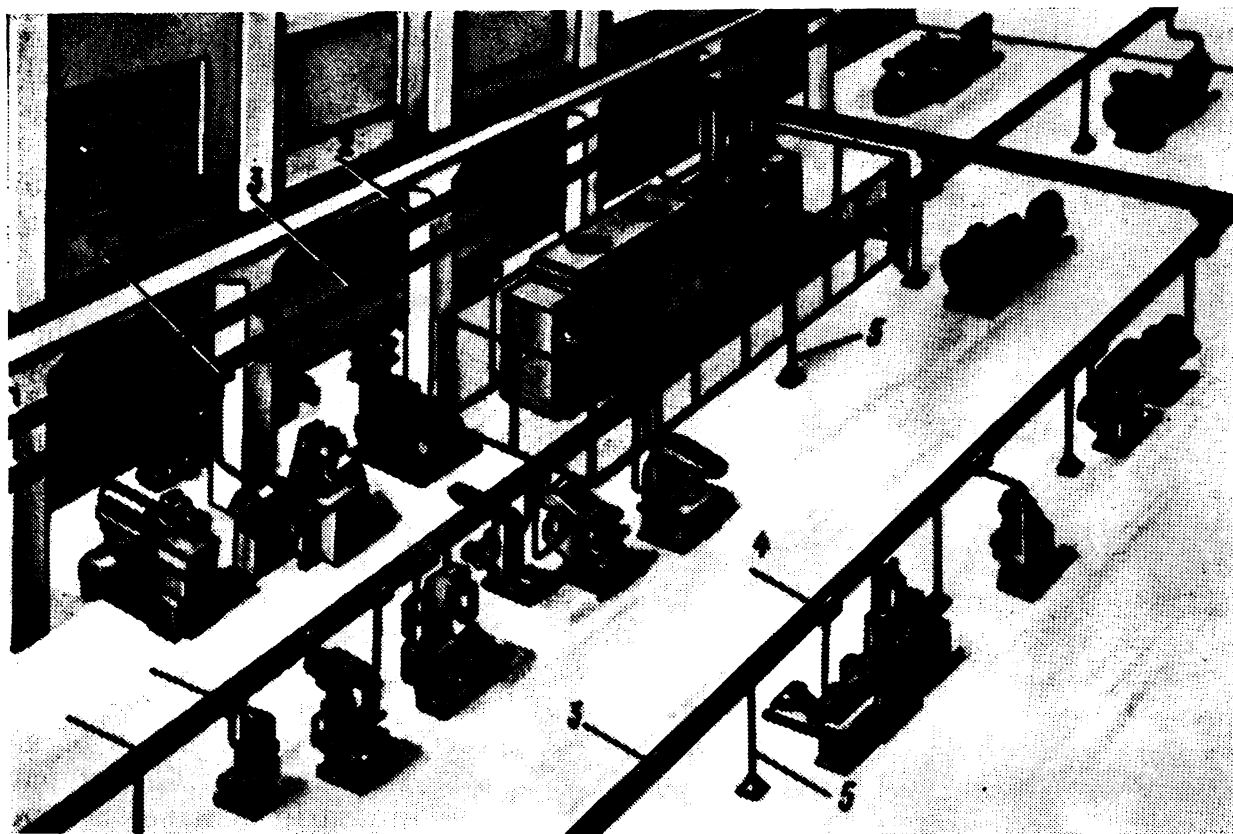


Fig. 117. Departmental distribution of electric energy via busways

1—unit transformer substation; 2—main-line busway secured on columns; 3—distribution busway installed on supporting structures; 4—branch box; 5—rack K881

Main-line and distribution busways composed of the type IIIMA and IIIPA busbar sections installed in industrial shops are illustrated by Fig. 117.

8.2. Basic Information on Electric Motors

Electric motors are machines in which electric power is converted into mechanical energy.

There are many types of electric motors. Most widely used of them, however, in all the branches of industry are three-phase induction motors.

Electric motors are characterized by their rated data specified in their certificates and indicated on the nameplates, viz., output power, voltage, stator current, starting-to-rated current ratio, power factor ($\cos \varphi$), rotor speed, rated torque.

The rated output power is a mechanical output power on the motor shaft at rated current, voltage, and frequency

$$P = 1.73VI\eta \cos \varphi$$

where V is voltage between lines, V; I is motor input current, A; η and $\cos \varphi$ are motor efficiency and power factor, respectively.

The rated current is the input current of the motor at rated loads, frequency, and voltage.

The starting current is the current flowing through the motor windings at the moment of its starting.

The starting-to-rated current ratio is the ratio of the current carried by the motor windings at the moment of starting to the rated current of the motor.

The power factor ($\cos \varphi$) is the ratio of the motor output power (P) to the gross power (S), that is,

$$\cos \varphi = \frac{P}{S}$$

The efficiency is the motor rated output-to-input power ratio.

The rated torque is the torque developed by the motor at the rated power output and speed.

A three-phase induction motor consists of a stationary part, viz., a stator, and a rotating part, a rotor, whose shaft is mounted in bearings accommodated in end shields.

The stator (Fig. 118a) consists of a frame 1, an iron stack 2, and a winding 3. The frame is a cast-iron or steel structure. The iron stack is built up of thin electric sheet steel stampings. Shaped cuts in the stampings, when the latter are stacked, form slots accommodating the stator winding. The number of pole pairs of the winding depends on the motor speed. The most popular induction motors are those with pole pairs of 2, 4, 6, and 8 for synchronous speeds of 3,000, 1,500, 1,000, and 750 r/min, respectively.

The actual speed of an induction motor is 3 to 6 per cent lower than the synchronous speed because the rotor slightly lags behind the revolving field of the stator.

The rotor consists of a steel shaft carrying a wound iron stack or core. The rotors may be of a squirrel-cage or wound construction.

A squirrel-cage rotor (Fig. 118b) is wound by injecting molten aluminium in the core slots. In the process, the rotor fan blades 5 and the end rings 4 are cast integral with the winding. The fan blades function to provide circulation of cooling air while the motor is running, thereby ensuring better cooling conditions.

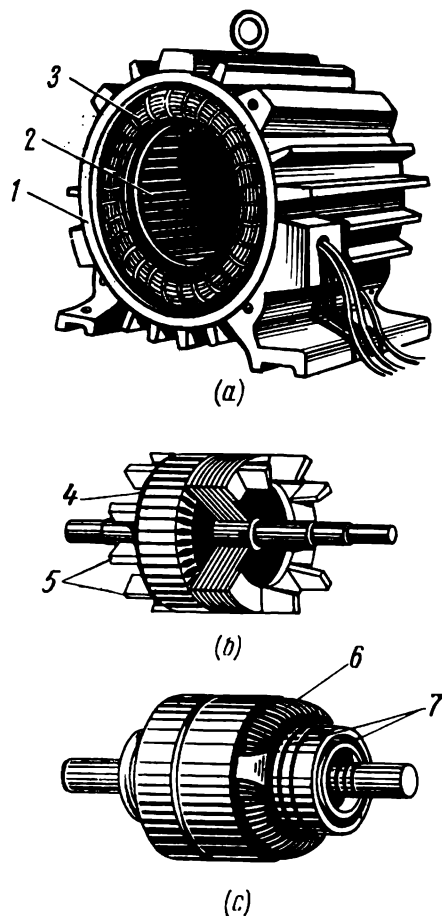


Fig. 118. Basic parts of an induction motor

a—stator; b—squirrel-cage rotor; c—phase-wound rotor; 1—frame; 2—iron stack; 3, 6—windings; 4—end ring; 5—fan blades; 7—slip rings

The squirrel-cage motors are started by across-the-line connection without starting and control gear, with the result that heavy starting currents are produced.

The advantages of squirrel-cage motors are simple construction and reliable operation of these machines. The disadvantage is heavy in-rush current at starting that greatly exceeds the rated current (6 to 7 times). Under such conditions the motor may fail to start if the power source (current transformer, mobile power plant generator, etc.) has insufficient capacity.

A wound rotor (Fig. 118c) accommodates in its slots a phase winding 6 made of insulated strips or conductors and has three slip rings 7 made of steel, copper or

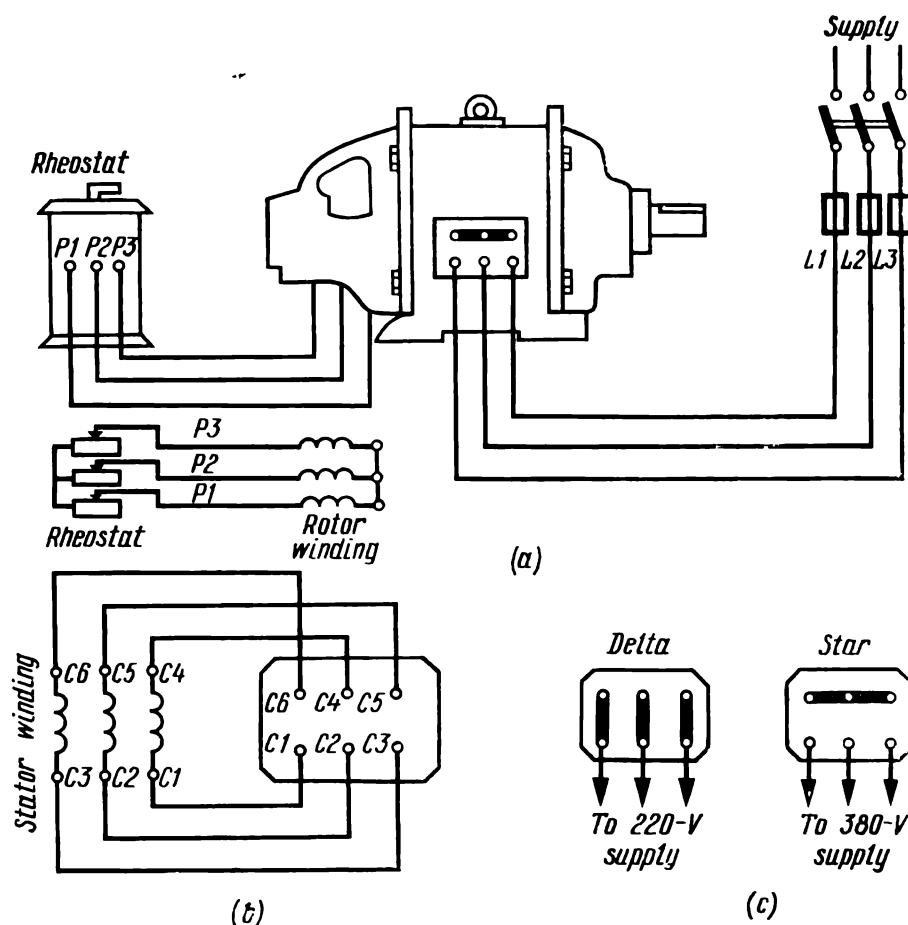


Fig. 119. Connection of induction motor windings

a—to supply mains; b—connection of rotor and stator windings; c—on terminal board

brass. The slip rings are insulated from each other and from the shaft. Such a construction makes it possible to connect the motor to power supply in series with a starting rheostat (Fig. 119a, b, c.), thereby ensuring a smooth starting (without heavy starting currents). A motor rated at 380/220 V, when connected to 220-V supply, has its stator winding leads connected in delta by shorting them out through jumpers as follows: C6-C1, C4-C2, and C5-C3. To connect this motor to 380-V supply, its stator winding leads are connected in star by shorting out their leads C6, C4 and C5 through jumpers.

Slip-ring motors are used where smooth starting is needed. The motor stator is closed at the ends with end shields, which accommodate bearings mounting the rotor shaft. The end shields also function to protect the rotor winding and other parts located within the stator against mechanical damage.

Squirrel-cage and slip-ring motors rated at up to 100 kW are furnished with ball and roller bearings. One of the rotor bearings is usually of the ball type and the other is a roller bearing. The roller bearing is usually installed on the drive end of the shaft where the shaft extension mounts a pulley or a half-coupling and the bearing must take heavy thrusts. Bearings mounted in end shields may be of an enclosed type with two bearing caps, open without bearing caps, or with a single internal cap. Induction motors are available in open, protected, totally enclosed, and explosion-proof design alternates.

Open constructions are used in normal locations where the current-carrying and rotating parts of the motor do not need protection against accidental contact with them or against foreign objects getting in the motor interior.

Motors coming in protected enclosures have their current-carrying and rotating parts protected against accidental contact with them and against foreign bodies. Protected motors are distinguished as drip-proof machines protected against vertically falling drops and splash-proof motors protected against splashes falling at an angle of up to 45 deg.

Dust-tight motors are meant for use in locations where the atmosphere is saturated with conducting dust. Motors designed for operation in explosion-hazard locations come in explosion-proof enclosures.

There are also motors of special design forms distinguished by the method of attachment to the driven mechanism, such as flange-mounted, built-in, etc.

Induction motors are manufactured in standard ranges or lines. Each standard range of motors comprises machines similar in mechanical design and different in power output. General-purpose three-phase induction motors of 0.6 through 100 kW output make up a single standard range. Cast-iron frame motors bear letters A or AO in their type designation to identify protected and totally enclosed machines, respectively. The respective type designations for aluminium frame motors are AJI and AOJI. The type designation of induction motors also contains code numerals indicating the following: stator core diameter (or motor size) is designated by numerals 3 through 9, stator core length is coded 1 through 3. Numerals standing after letter codes stand for the core size, core length, and number of pole pairs. For example, the type designation AOJI-52-4 should read as follows: an aluminium-frame totally-enclosed fan-cooled motor, size 5, core length 2, four-pole.

8.3. Mechanical Design of Induction Motors

The general arrangement of a squirrel-cage induction motor is illustrated by Fig. 120*a*. All the motor parts are totally enclosed, that is, its frame and end shields are not provided with ports for the admission and exhaust of cooling air. Fan blades 5 on the rotor end rings function to force hot air through cooling ducts provided in the rotor and in the stator frame, thereby causing its circulation and

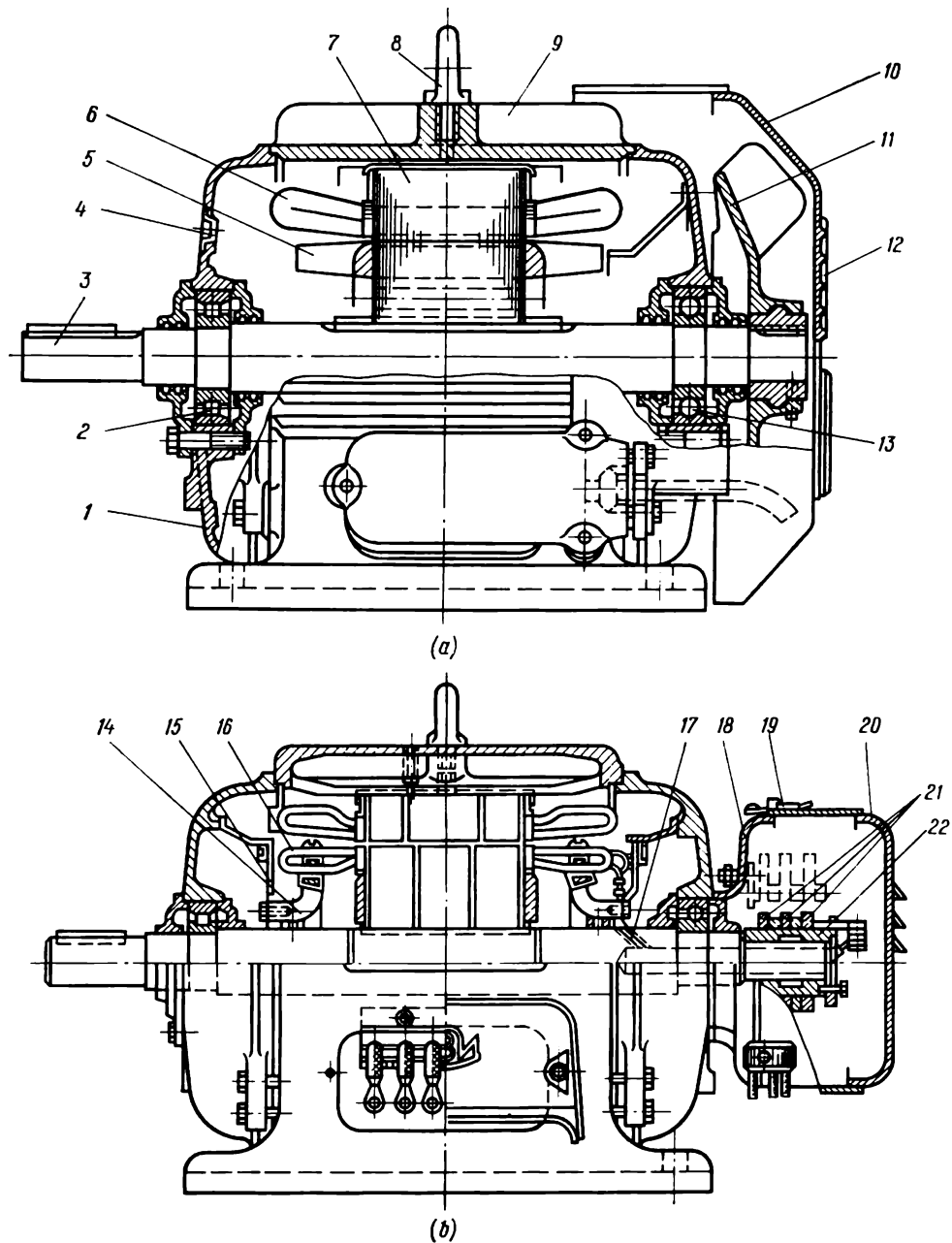


Fig. 120. Three-phase induction motors

a—squirrel-cage; b—slip-ring; 1—end shield; 2—roller bearing; 3—shaft; 4—access port for checking air gap between stator and rotor stacks by means of a feeler gauge; 5—rotor fan blade; 6—stator winding; 7—stator stack; 8—eye-bolt; 9—frame rib; 10—protective cowl; 11—fan; 12—ports to admit air forced by the fan; 13—ball bearing; 14—winding holder; 15—balance-weight mounting disk; 16—slip-ring motor rotor winding; 17—rotor winding leads brought out to slip rings; 18—housing; 19—latch; 20—hood; 21—slip rings; 22—bush insulating slip rings from the shaft

ensuring a uniform heating of all the motor parts. Hot air is carried away towards the stator frame walls fitted with longitudinal ribs 9. The outer surfaces of the ribs are cooled by air delivered by a cast aluminium fan 11. Cooling air is drawn in by the fan through ports 12 provided in the sheet steel protective cowl 10. An access hole 4 is made in the end shield that is used to check the air gap between the stator and rotor stacks with the aid of a feeler gauge. Moisture may condense within a totally enclosed motor in the event of its operation at abrupt variations in ambient temperature. A drain hole is provided at the bottom of the frame to discharge condensate.

A slip-ring induction motor is shown by Fig. 120*b*. The rotor slots accommodate a three-phase winding 16 held in position by winding holders 14. Screwed to the winding holders are stamped balance disks 15 carrying balance weights. The rotor end windings and the protruding portions of the winding holders carry away the surrounding air while the motor is running, thereby functioning as fan blades. The rotor winding has three terminal leads 17 brought out through the hollow shaft and connected to slip rings 21. The slip rings are insulated from each other with insulating washers, and from the shaft with an insulating bush 22. The slip rings are in contact with brushes secured to brush holders. The brush gear is accommodated in a housing 18 and closed with a hood 20 that is locked with a latch 19.

The diameter of the bearing seat in the end shield is larger than the outer diameter of the slip rings. Such an arrangement makes it possible, whenever required, to pull off the end shield without removing the slip rings.

The steel housing is fitted on the bearing cap and bolted to the end shield. The housing accommodates a steel spindle carrying brush holders insulated from the former with an insulating bush. The brush pigtails are secured at the exit from the terminal box with two beech planks boiled in oil.

8.4. Installation of Electric Motors

8.4.1. Handling, Inspection, and Drying-Out

Motor handling includes its loading, unloading, hoisting, lowering, and haulage. All these operations are referred to as hoisting and haulage jobs.

Electric motors having a mass in excess of 80 kg are handled by means of slings (Fig. 121*a, b*) and various mechanisms (Fig. 121*c, d*). A portable lever hoist (Fig. 121*d*) having a mass of about 18 kg and a load-carrying capacity of 1,500 kgf is most suitable for the purpose. The hoist is furnished with a cam gripper and a traction mechanism that function to move its rope 15 up or down by rocking levers 11 and 13. A single stroke of the lever moves the rope through 36 mm. The hoist is carried by a hard handle 12 fitted on its right-hand side cover. Each hoist comes complete with a holder that receives the operating rope, dia 11.5 mm, with a hook.

Horizontal and inclined haulage of large electric motors is carried out by a hand-operated or a motor-driven hoist. The hoist must be mounted so that the driving end of the rope approaches the drum from the bottom. The rope diameter is selected depending on the motor mass and taking into account the load-carrying capacity of the hoist.

The sling must never be selected "by eye" or approximately as it may lead to its breakage with the result that the motor may be damaged or an accident may occur. That is why, while preparing the motor for handling, make simple calculations to be sure that the rope selected will sustain stresses created in it while handling the equipment.

For horizontal and inclined haulage of a motor by a hoist, the stress P , kgf, in the rope is determined from the equations:

for horizontal haulage

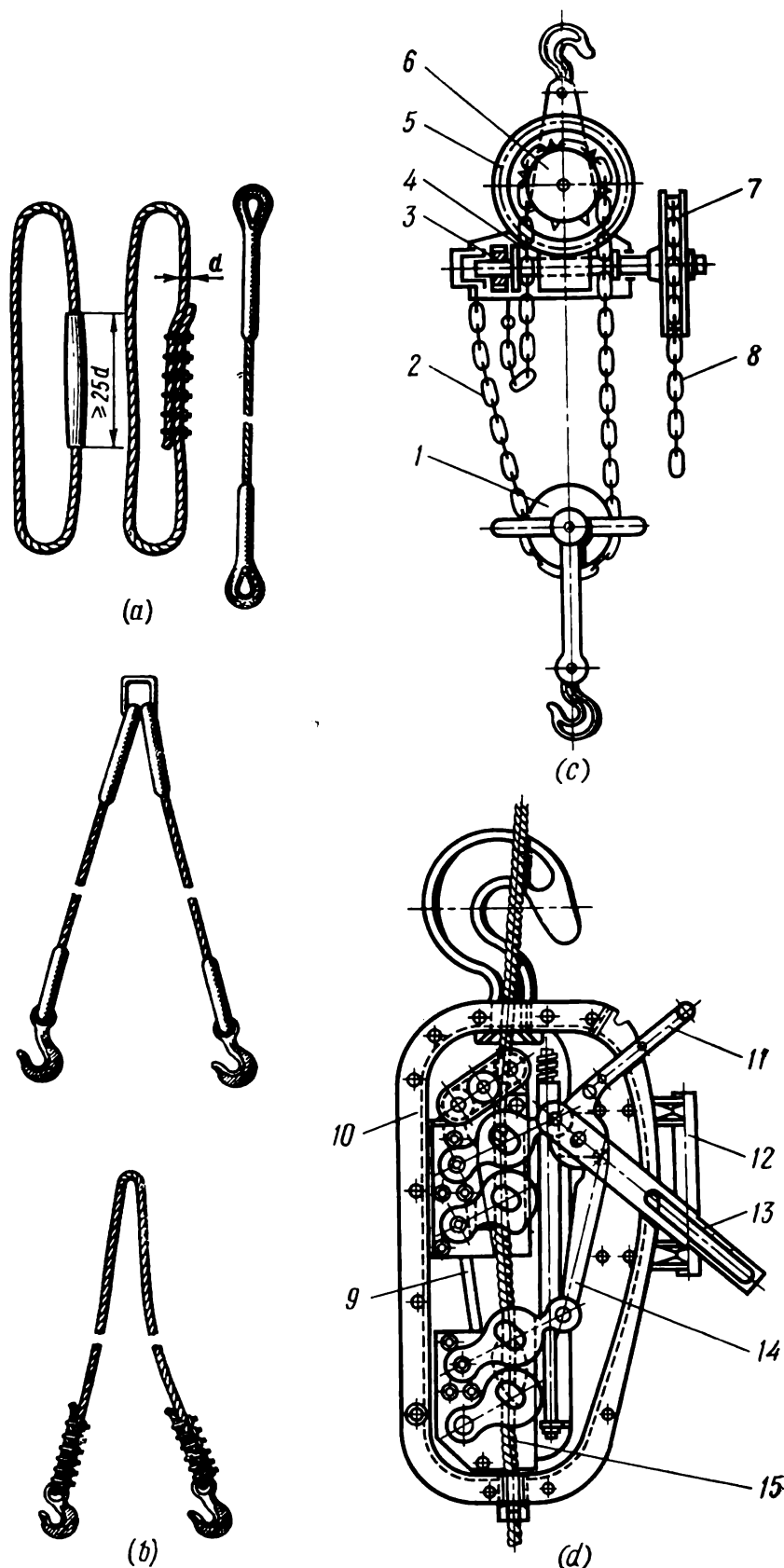
$$P_h = fQ$$

for inclined haulage

$$P_i = Q(f \pm a)$$

Fig. 121. Slings and hoists for hoisting and haulage of motors

a —light-mass slings; b —multipurpose slings; c —chain hoist; d —lever-type hoist with side wall removed; 1—pulley; 2—lifting chain; 3—brake; 4—worm; 5—lifting wheel; 6—sprocket; 7—drive wheel; 8—operating chain; 9—control rod; 10—housing flange; 11—reversal lever; 12—handle; 13—forward run lever; 14—carrier; 15—rope



where Q is load mass, kg; a is hoisting coefficient equal to H/L with the plus sign in hoisting and the minus sign in lowering; H is hoisting depth, m; L is path length over inclined surface, m; f is friction coefficient assumed to be 0.2 for steel skids moving over a steel surface, 0.4 for wooden skids moving over a wooden flooring, and 0.7 for those sliding over dry earth.

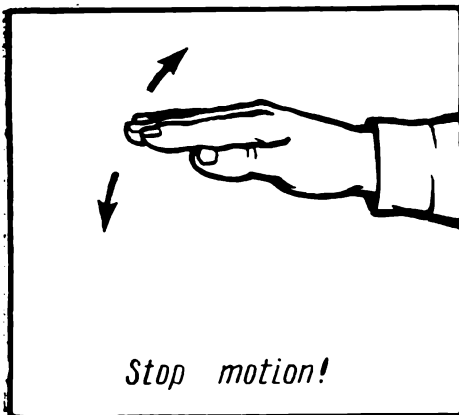
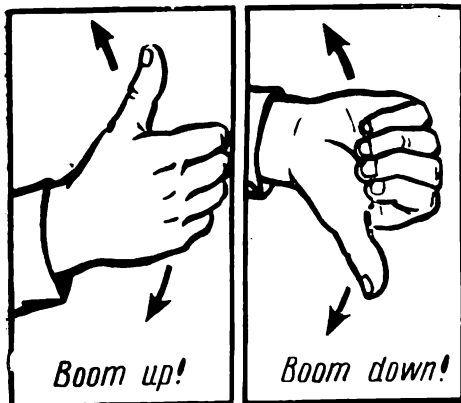
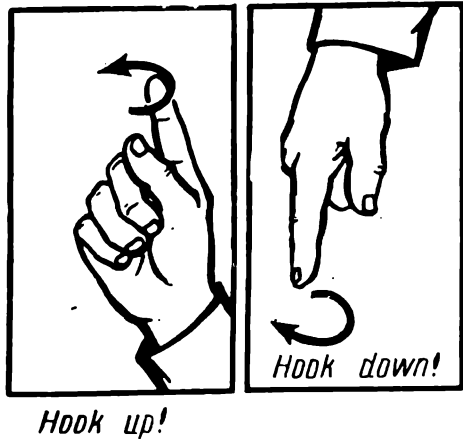


Fig. 122. Signs applied by hand to crane operator

Mechanisms used for handling electric motors must be in good condition; ropes, slings, and chain hoists employed must be appropriately tested, labour protection must be ensured, and safety precautions strictly observed.

In handling electric motors a limited number of voice commands are used. The "Up", "Down", and "Stop" commands are used to lift, lower, and stop the motor, respectively. Any of these commands can be restricted by adding "A bit"; for example, "A bit up". In noisy locations where the operators (a hoist operator or a crane operator) may fail to hear the command, command signs are applied by hand (Fig. 122).

Electric motors delivered on site in an assembled condition do not usually need a comprehensive test since they are issued by the manufacturer fully tested and ready for installation. Damage may occur, however, if motors are shipped or stored under abnormal conditions. For example, windings may be moistened or contaminated, insulation of end windings of open motors damaged, bearings broken. If this is the case, the motors must be subjected to a condition inspection that may or may not involve the removal of the rotor. The motor shall be disassembled only in case the trouble cannot be remedied and when the repair is possible on the installation site.

To facilitate the work, special tools and fixtures shall be used for the disassembly and reassembly of electric motors.

The motor disassembly is started from the removal of the half-coupling or pulley from the shaft extension by means of a universal manual or hydraulic puller (Fig. 123a and b, respectively).

The manual puller with an adjustable separation of operating rods (Fig. 123a) makes it possible to grip parts of all sizes from inside or outside and to remove them. The operating (hooping) rods are separated and fixed in position according to the size of the part to be removed by means of an adjusting nut 2 turned onto the threaded portion of

the screw 1 with a head. The tractive force afforded by the puller is 2 to 2.5 tf.

A more advanced facility that can be employed for pulling half-couplings and pulleys off the shaft extensions of large electrical machines is a type $\Phi K-2-10$ hydraulic puller (Fig. 123b) affording a tractive force of up to 10 tf. The end of the hydraulic puller screw is fitted with a ball 4 that protects the centre of the motor shaft against damage (nicks) which may otherwise take place due to heavy tractive forces applied.

Special pullers are used for the removal of antifriction bearings from the motor shaft. The one illustrated by Fig. 123c grips the bearing by its race and that shown

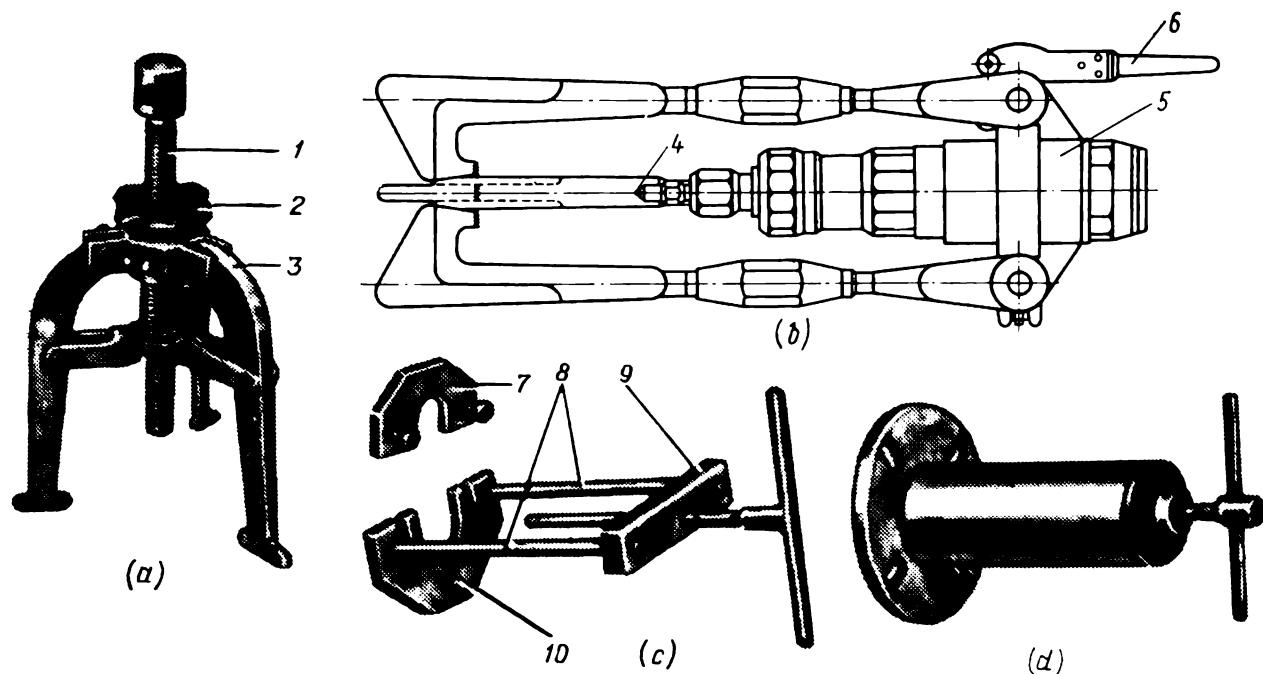


Fig. 123. Universal pullers

a—manual puller for removing half-couplings and pulleys from the shafts of small- and medium-sized machines; b—hydraulic puller for half-couplings and pulleys of large machines; c—pulley for removing bearings by the race; d—pulley for removing bearings by the cap or housing; 1—worm screw with head; 2—adjusting nut; 3—hooking rod; 4—steel ball; 5—tank; 6—hydraulic pump handle; 7—plate with pins; 8—studs; 9—crossarm; 10—plate

by Fig. 123d catches with its bolts the bearing cap or housing. To remove the bearing, it is necessary to turn out the bolts, nuts, and retainers. When the hooping rods (plate 10) of the puller are placed on the bearing, care shall be taken that their bosses catch the inner race of the bearing and not the outer one, otherwise the bearing may be damaged.

If the puller force is insufficient, the parts to be removed shall be heated as follows: pulleys and half-couplings are heated in the flame of a torch or a gas burner to a temperature of 200 to 250°C, the shaft being cooled at the same time with water or compressed air; bearings are heated by pouring on them clean transformer oil heated to 100 or 120°C.

A newly installed bearing shall be preheated in a bath filled with clean mineral oil to a temperature approaching 100°C. Just before fitting the bearing on the

shaft, the shaft extension and the bearing seat shall be flushed in petrol, wiped with clean waste, and coated with mineral oil. The new bearing is fitted on the motor shaft with the aid of a pipe length, better copper one (Fig. 124a), and driven into the end shield bore with the aid of a pipe length and a steel washer, 4 or 5 mm thick (Fig. 124b). The outer diameter of the pipe length shall be 2 or 3 mm smaller

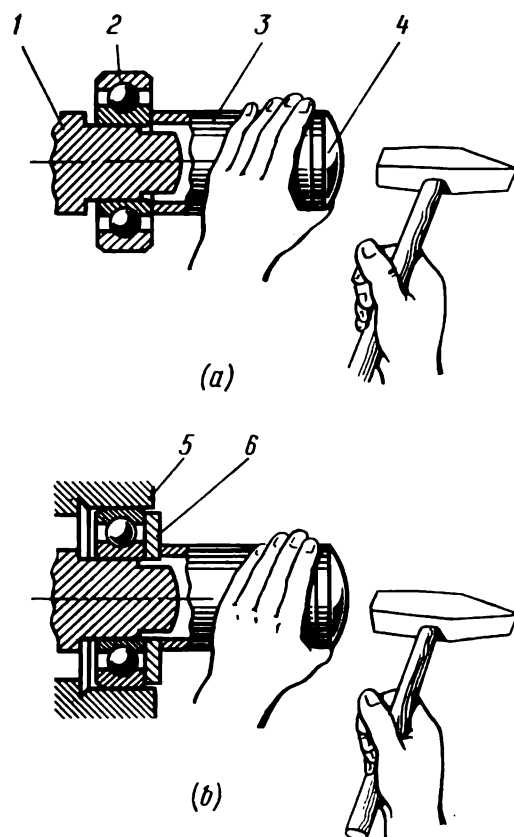


Fig. 124. Mounting the antifriction bearing

a—on the shaft; b—in the end shield bore;
1—shaft; 2—bearing; 3—pipe length; 4—
spherical end cap; 5—end shield bore; 6—
steel washer

than that of the inner bearing race. A spherical end cap shall be fitted on the pipe end.

When a rotor as heavy as 50 kg is to be removed from the stator, the sling rearrangement method or a special facility shall be employed.

The sling rearrangement method needs a crane or any other hoisting mechanism of the desired load-lifting capacity. The sling rearrangement method consists in that slings 1 are fitted on the rotor shaft (Fig. 125a), and pulled by the crane so as to have the rotor as if suspended from the slings. Then the crane is moved to bring the rotor out of the stator until the rear sling approaches the stator end winding (Fig. 125b). Afterwards, a sheet of press-board is placed on the stator stack, the rotor is lowered onto it, the pipe 2 is fitted on the shaft, and the rear sling is brought to it. The rotor is then moved further and brought out of the stator through a certain distance, the shaft extension is lowered on the support 4, then the slings are rearranged onto the middle portion of the rotor stack so that the centre of gravity of the rotor is between the slings (Fig. 125c). Then the rotor is fully brought out of the stator.

Heavy rotors are brought out of the stators by means of special pullers secured on the stators (Fig. 125d). The puller consists of a

rail length or a steel beam, a set of rollers, and bands supporting the rotor shaft.

Condition inspection involves a thorough examination of all the motor parts and assemblies, starting from the insulation and fastenings of the end windings; then the insulation resistance of windings is checked with the aid of a megger.

If the insulation resistance of the motor windings is below 0.5 MΩ, the windings must be dried out.

There are many methods of drying the motor windings, each one being selected to suit the motor output and mechanical design. For motors rated up to 15 kW, infrared lamps or standard incandescent lamps of up to 500 W are used; for motors rated from 15 to 40 kW use is made of hot air supplied from a hot air blower, or of electric current passed through the windings; for motors rated from 40 to 100 kW

the windings are dried out by eddy current loss in the stator stack. Each of these methods is briefly discussed below.

For drying out with the aid of lamps or by means of hot air, the heat source is placed in the former case within the motor, and in the latter near the windings; the motor is closed with a cowl provided with ports for the escape of evaporating moisture.

Drying out by electric current passed through the motor windings can be carried out both by d.c. and single-phase or three-phase a.c. power. Three-phase

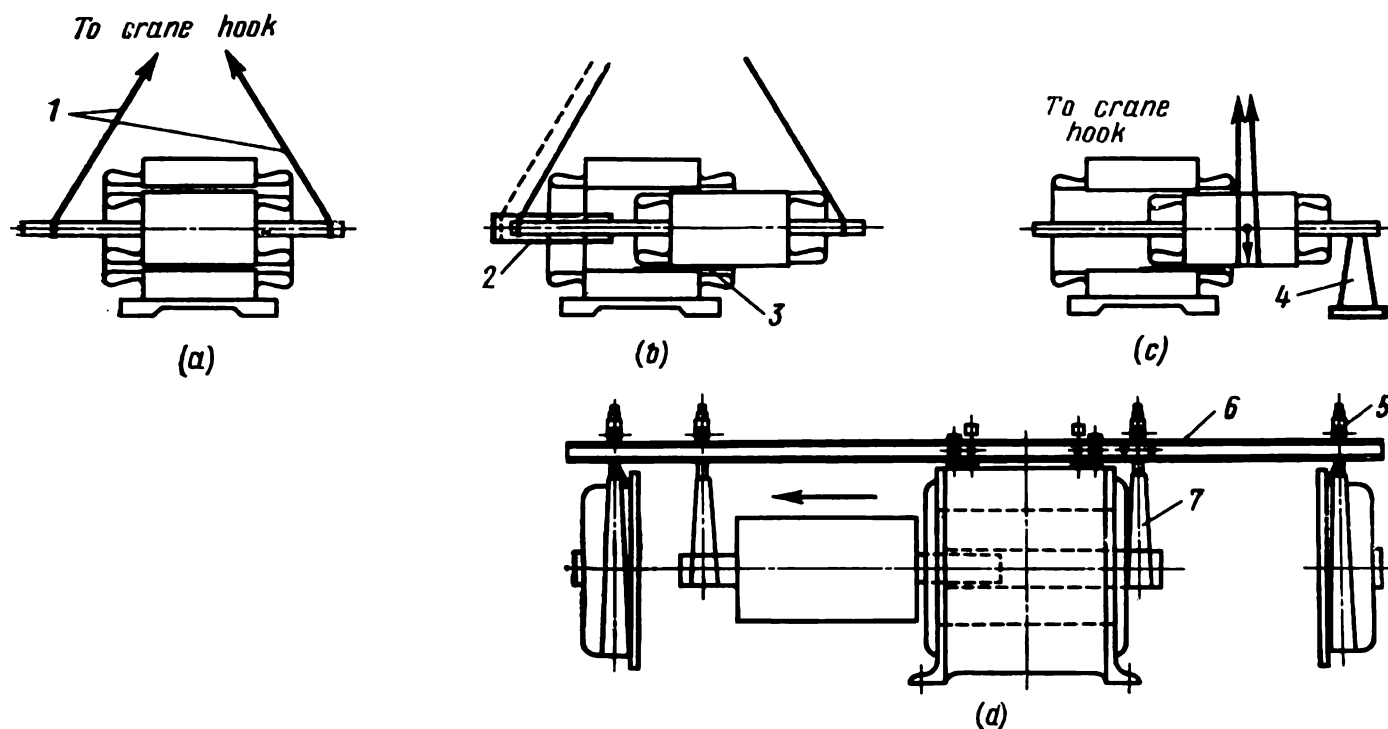


Fig. 125. Methods of driving the rotor out of the stator

a, b, c—successive stages of re-arrangement; d—using a fixture; 1—slings; 2—steel pipe fitted on the shaft; 3—pressboard spacer; 4—shaft support; 5—castors; 6—monorail mounted on the motor frame; 7—steel tape loop (band)

current is most frequently used for the purpose. Three-phase current is applied to the stator winding with the rotor locked. The motor winding is dried out due to heating by short-circuit current. The current required to heat the winding to 80 or 90°C is controlled by applying a reduced voltage usually making up 12 to 15 per cent of the rated value. The current flowing in the stator winding shall not exceed 70 per cent of the rated value, otherwise the winding temperature may rise to a dangerous value due to the absence of ventilation.

In order to reduce the drying time, it is good practice to unlock the rotor and to allow it to run for 5 or 6 min so as to force cooling air and to allow moisture evaporation from the winding.

The winding of a slip-ring motor shall be short-circuited for drying out by setting jumpers on the slip rings. Prior to starting the drying procedure, the motor frame must be reliably earthed.

When drying out by eddy current loss in the stator stack, the winding does not carry current and is heated due to loss caused by a reversing flux created by a magnetizing coil wound on the motor stator core and frame. The rotor is removed from the stator, and a few turns of wire with heat-resistant insulation are wound through the stator bore. The magnetizing coil is supplied with a voltage lower than 60 V from a welding transformer. The cross-sectional area of the magnetizing coil wire and the number of turns are found by calculation or taken from reference books.

Whatever the above-discussed method used, care is taken that the temperature of windings in the course of drying should never exceed the values specified by the USSR Standard GOST for the particular insulation class. The recommended drying temperature for motor windings is 80 to 90°C.

Drying conditions are checked up by a megger and thermometers. Thermometers are wrapped in aluminium foil at the bottom (the mercury bulb) and fixed in position at the hottest spots of the winding. Insulation resistance is measured every hour by means of a megger. At the beginning of the drying procedure the insulation resistance may decrease due to moisture evaporation from the winding, then it gradually increases and at the end becomes steady. The drying procedure may be terminated if the insulation resistance of the stator winding of a 500-V motor remains steady for 2 to 4 hours and is not lower than 1 MΩ.

The results of drying are entered into a report which includes the motor nameplate data, place of installation, drying methods, schemes and parameters of drying (current, voltage, time, insulation resistance and heating temperature measurements made).

After the faults detected are eliminated and the winding is dried out, the motor may be reassembled.

8.4.2. Motor Reassembly and Installation

The motor is reassembled using the same procedure as during its disassembly, but in the reverse sequence.

The rotor is inserted into the stator by means of special appliances taking care not to injure the winding. Then the end shields are attached to the frame.

While placing the end shields in position, they may be tapped over the circumference with a hammer through a wooden or lead adapter or spacer till they are fitted on their seatings on the frame without misalignment.

After the end shields are placed in position, the motor shall be checked for easy rotation of its shaft and for any seizure between its rotating and stationary parts. A tight rotation of the shaft is the indication of misalignment in the bearings or in the end shields. Brushing of rotating parts against stationary ones points to inadequate gaps between them and, primarily, between the rotor and the stator.

The air gap between the rotor and the stator is measured with a feeler gauge (Fig. 126*a*, *b*) at four points (Fig. 126*c*) equally spaced along the circumference; the air gaps at all the four points must be accurate to 10 per cent. The feeler gauge is inserted in the air gap between the stator and the rotor on both ends of the

motor. Measurements are repeated twice or thrice, each time rotating the shaft through 90 or 180 deg. The air gap between the stator and the rotor is very small. Motors of the standard range A rated at 55 kW, 3,000 r/min have an air gap of 1.4 mm, and those rotating at a speed of 1,000 r/min merely 0.6 mm. It is very important to keep the air gap within specified limits to ensure normal operation of the motor. It shall be borne in mind that too large an air gap causes abnormal operation of the motor, while too small a gap tends to burn the stacks as a result of seizure between the stator and the rotor.

After the motor is reassembled and appropriately tested, it may be installed in position. The motor is installed on a fabricated bedframe — a cast-iron slab, or mounting skids prepared in advance and fixed to the foundation with anchor bolts.

Motors weighing up to 80 kg are to be lifted on a foundation of up to 1 m manually by dragging them over an inclined boarding; those heavier than 80 kg are lifted by means of suitable hoists.

When the motor is coupled to the driven mechanism via a belt or a V-belt, the shafts of the both must be strictly parallel. The horizontal alignment of the shafts is checked

by means of thin steel wire or twisted twine strings proceeding as is shown by Fig. 127. If the pulleys are of an equal width, parallel alignment of shafts can be achieved as soon as points *A*, *B*, *C*, and *D* come in contact with the string simultaneously. If the pulleys are of a different width, the shafts are brought in alignment proceeding from the condition in which the distances from the centre lines of the pulleys to the string are equal.

If the motor is coupled to the driven mechanism via a flat belt or a V-belt, one of the belt tensioning screws must be located under the belt and the other on the diagonally opposite end.

If the motor is joined with the driven mechanism via a coupling, the shafts are aligned by aligning their centre lines. Prior to aligning the centre lines of the shafts, it is essential to make sure that the half-couplings are reliably fitted on the shafts. To this end, each half-coupling is tapped with a hammer, the joint between the half-coupling and the shaft being held at the same time with hand. Tapping with a hammer must not displace the half-coupling. The shafts are align-

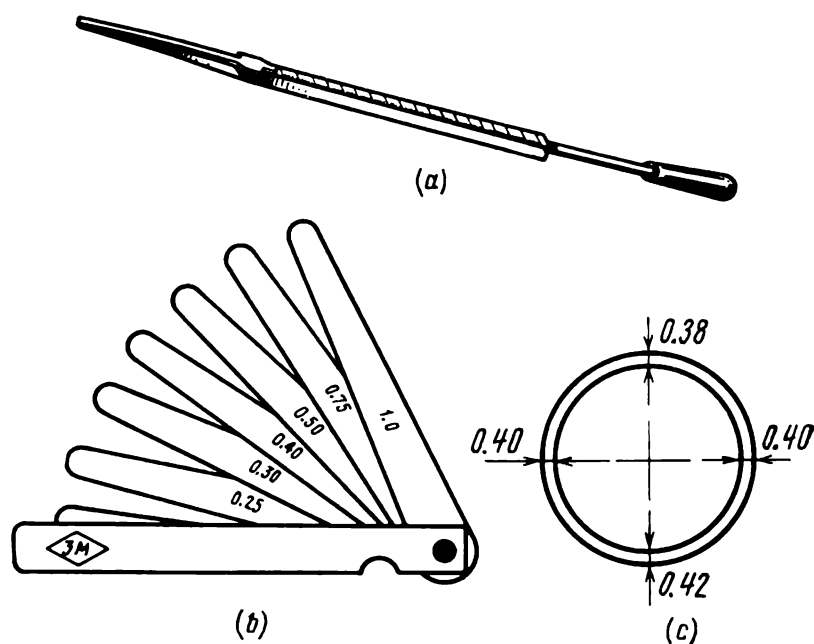


Fig. 126. Feeler gauges for checking the air gap between the stator and the rotor and points of measurement

a—wedge-type feeler gauge; b—flat feeler gauge; c—points of air gap measurement

ed by means of alignment fixtures (Fig. 128a). Fixtures 3 are secured on the half-couplings 1 and 4, the shafts turned through 90 deg, and clearances between the fixtures are measured at four positions of the shafts with a micrometer, then the motor is displaced to a position in which the difference between the clearances is the smallest. In the case of horizontal misalignment, the motor is displaced on the foundation; in the case of vertical misalignment, steel shims must be fitted under its feet. Not more than four shims may be placed under the motor feet. If

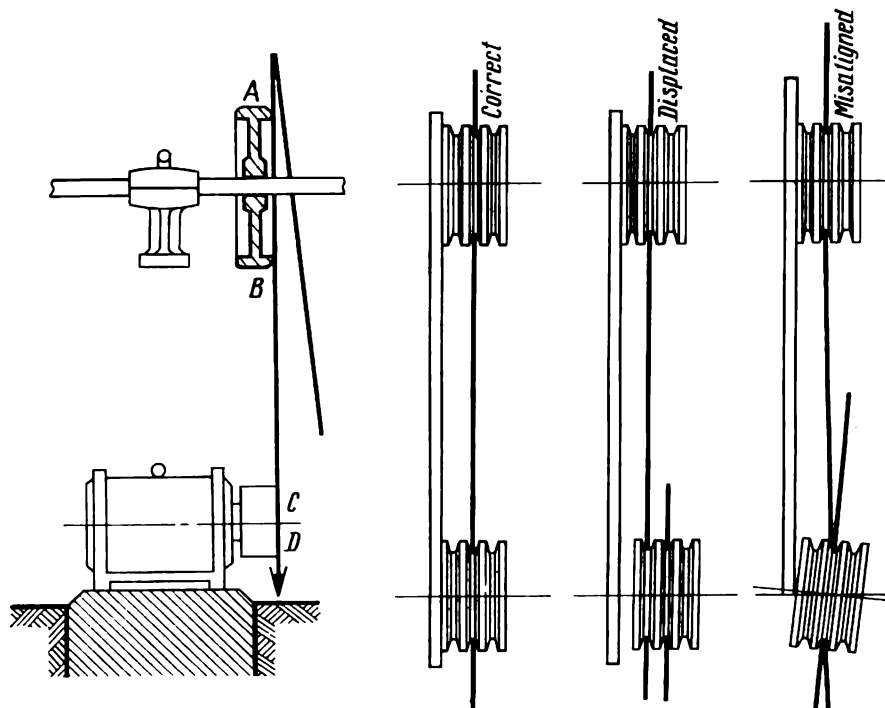


Fig. 127. Alignment of shafts for belt and V-belt transmission

this quantity of shims is insufficient to obtain the desired alignment, several thinner shims are replaced by a single one of a greater thickness. The shim thickness shall not be smaller than 0.5 mm. If a greater number of thin shims are inserted, the motor fixation and the alignment of shafts may be impaired in the course of operation.

Alignment of shafts mounting large half-couplings (200 mm and over) can be checked by measuring the clearances between the coupling surfaces (Fig. 128b). The shafts are checked for horizontal alignment by a feeler gauge 6, and for vertical alignment by a pin 5. In order to ensure correct measurements, the feeler gauge must be inserted between the mating surfaces of the half-couplings at several positions, and better between the same points. To this end, marking lines are made in chalk or in paint on the rims of the half-couplings.

The aligned motor must be rigidly bolted and then checked again for accurate alignment that may be disturbed in the course of its fixation.

Then the motor is earthed through its frame connected to the overall earthing system by a special busbar.

Slip-ring motors are installed in much the same way as squirrel-cage machines, the only difference being that additional work is required for the installation, connection, and earthing of a starting rheostat.

Fully mounted motors are given a trial run at no load and under a load.

8.4.3. No-Load and On-Load Trial of Motors

No-load trial starting of motors is intended to check the motor for the condition of its structural parts (for knocking noise, brushing of rotating parts against stationary ones, etc.), for sense of rotation, for proper fixation on the foundation, and for the alignment of shafts. In the process, the driven mechanism must run idle.

The motor is thrown across the line and instantly disconnected while it has not yet gained speed (as soon as it has accelerated to approximately 25 or 30 per cent of rated speed). In the process, one must listen to the noise produced by the rotor as it keeps rotating by inertia. No abnormal noise must be heard.

If the motor rotation must be reversed, any two adjacent supply leads connected to the motor terminals are interchanged.

After the trial start and elimination of troubles detected, the motor is given one more no-load run at full speed for an hour. During this period the electrician in charge must keep an eye on the motor and check heating of bearings every 10 to 15 min. The permissible temperature rise of the bearings above the ambient is maximum 60°C, and the permissible heating temperature is maximum 95°C as referred to 35°C ambient.

While the machine is running at no load, the bearings are checked for vibration by means of a vibrometer whose pointer indicates the amplitude of vibration.

The vibration of the motor bearings, that varies as a function of the rotor speed, shall not exceed the following values:

Synchronous speed, r/min	Maximum amplitude of vibration of bearings, μm
3,000	50
1,500	100
1,000	130
750 and lower	160

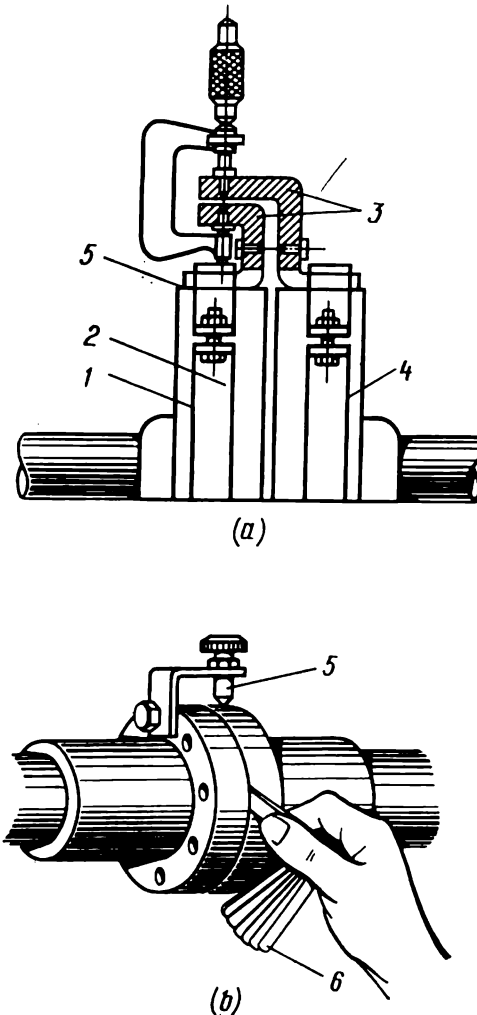


Fig. 128. Vertical alignment of shafts

a—with fixtures; b—with feeler gauge and pin; 1—motor half-coupling; 2—clip for fastening the fixture on the half-coupling; 3—fixtures; 4—driven mechanism half-coupling; 5—pin; 6—feeler gauge

Excessive vibration may be caused by many factors, such as loose fixation of the motor feet, insufficient rigidity of the foundation, misalignment of shafts, out-of-balance of the rotor, poor contact in a winding, etc. The cause of abnormal vibration must be found and the fault eliminated, otherwise damage to the bearings or foundation, and even failure of the motor may result.

If the motor operates normally at no load, it may be given a trial on-load run. This trial is also meant to check the motor for vibration and bearing temperature once more. This check is necessary because vibration and heating temperature of bearings may rise due to poor balancing or insufficiently rigid fixation of the driven mechanism. In the case of a belt drive, abnormal heating of bearings may be caused by excessive tensioning of the belt or pulley.

The motor shall be allowed to run under an almost rated load for at least 3 hours. Within this period the winding temperature is measured every 30 min and compared with the nameplate data or with GOST specifications for the insulation of the particular class.

8.5. General Information on Circuit-Opening Devices

Circuit-opening devices are pieces of electrical equipment specially designed to control, regulate, or protect electric circuits and machines. Circuit-opening devices are classified as follows:

according to application: on/off devices meant to switch on and off the electric circuits; protective gear intended to protect electric circuits and machines by disconnecting them from supply upon the occurrence of overloads and short circuits, inadmissible voltage fluctuations, and under various abnormal conditions; starting and control gear used for starting electrical machines, and regulating their speed, current and voltage; monitoring devices intended to maintain electric circuit characteristics within desired limits by responding to any deviations of controlled variables from the desired values and yielding current pulses which cause the operation of a signal or an on/off device;

according to principle of operation: contact-type devices that actuate the electric circuit under control by closing and opening the movable contact members; non-contact devices that control electric circuits connected to them by changing their electrical characteristics (inductance, capacitance, resistance, etc.);

according to voltage handled: low-voltage devices (up to 1,000 V, but most often up to 660 V) and high-voltage devices (over 1,000 V, but most often 6 kV and higher);

according to current system: d.c. and a.c. devices;

according to enclosure: open, protected, explosion-proof devices, etc.

Circuit-opening devices may also be classified by other characteristics, such as the *number of poles* (single-pole or three-pole), by *arc control method* (deion-grid, oil-blast, or gas-break), by *their action* (electromagnetic, thermal, induction).

The circuit-opening devices are designed and manufactured in compliance with various standards. All of them shall meet the following general requirements:

(a) current-carrying parts must sustain continuously flowing rated currents

without abnormal heating, and also short-time overload and throughput short-circuit currents;

(b) the contact members and the operating mechanism must afford as many on/off cycles as specified by the manufacturer without disturbance of their adjustment;

(c) the contacts shall be capable of making and breaking all the working currents and those of many devices must also sustain specified abnormal currents;

(d) the component parts of the devices must sustain electrodynamic forces due to overload or short-circuit currents flowing in the current-carrying parts and remain serviceable after the abnormal condition is cleared;

(e) the device insulation must afford a reliable and trouble-free operation at preset voltages and also at short-time surge voltages of specified values.

The main and most important parts of commercial circuit-opening devices are their contacts.

Contacting surfaces, even those well polished, have almost invisible roughness. That is why the actual contact is made at separate points only and not over the entire contact area. These points are called making points. Contacts which do not suffer heavy pressures while making (pressures bringing the contact members in close contact) have a negligible number of making points.

Under a heavy pressure on the contact members the rough surfaces are smoothed down and the initial making points are transformed into making areas. The number of making points and their areas increase with pressure applied to the contact members.

It shall be borne in mind, however, that with a further increase in the contact pressure the formation of new making points is retarded since this pressure is gradually taken by a greater number of points having a larger area, and the specific pressure at the making point drops, with the result that the material of the contacts yields more reluctantly.

Current is transferred from one contacting surface to the other through making points, that is, through very narrow areas. The resistance at the contacting surfaces is determined by that at the point of current transfer and is called contact resistance.

The contact resistance is one of the most important characteristics of the quality of the device contacts.

The quality of device contacts depends not only on the contact pressure but also on the contacting surface finish. Poorly finished and oxidized surfaces have a high contact resistance. When mounting and wiring circuit-opening devices, particular attention must be given to the condition of their contacts. Oxidized contacting surfaces of copper contacts must be filed off to obtain the required roughness for the contact between rough surfaces is much better than between ground or polished ones. The surfaces of contacts must be clean and the contact pressure must comply with the manufacturer's specifications.

Most circuit-opening devices manufactured in recent years have sintered-metal clad contacts noted for high mechanical strength and thermal stability. Sintered-metal cladding is made by moulding powdered refractory metals (tungsten, molybdenum) mixed with powdered conducting metals, such as copper and silver. Sin-

tered-metal plated contacts are cleaned by flushing them in pure petrol. They must never be filed off.

Circuit-opening devices delivered to the installation site in factory packing and showing no sign of damage shall not be opened or dismantled. Minor defects shall be remedied so that the factory set-up and adjustment of contacts, operating mechanism and other parts of the device be retained as much as possible.

8.6. Mechanical Design of Circuit-Opening Devices

Circuit-opening devices designed to control electric circuits fall into non-automatic and automatic groups.

Non-automatic devices are knife switches, change-over switches, packet switches, starting gear boxes, drum switches, and controllers. All these devices are controlled manually by the operator.

Automatic devices are contactors, magnetic starters, and circuit breakers which are controlled remotely or automatically under abnormal conditions occurring in a motor or in supply mains (overload, voltage drop or failure, etc.).

8.6.1. Non-Automatic Circuit-Opening Devices

The knife switch (Fig. 129a) functions to connect or disconnect electric motors and to make or break electric circuits under normal conditions, and also to disconnect them under abnormal conditions at no load. In the latter case it is used as an isolating switch.

The change-over switch (Fig. 129b) is primarily used to change over squirrel-cage induction motors from star to delta when starting them so as to reduce starting currents, and also to switch over electric circuits rated at 220 and 380 V.

The packet switch (Fig. 129c) is designed to switch on or off electric motors and to make or break electric circuits rated up to 380 V. It consists of a stack of single-pole plastic rings accommodating contacts and arc-control devices, separate for each pole.

The starting gear box (Fig. 129d) is a device incorporating in addition to knife switches, a set of fuses affording the protection of electric motors against overloads and of electric circuits against heavy currents that may be caused by overloads or faults in the motor controlled. Starting gear boxes are employed as manual control devices for electric motors operating on up to 500 V supply; they are fitted with a special interlocking device which makes it impossible to open the door with the knife switch in the on-position or to close the knife switch with the box doors open.

The drum switch (Fig. 129e) is used as a non-reversible starter of electric motors that shorts out fuses for the period of starting or changes the motor over from star to delta.

The controller (Fig. 129f) is used where special starting conditions shall be afforded, such as, motor reversal, etc.

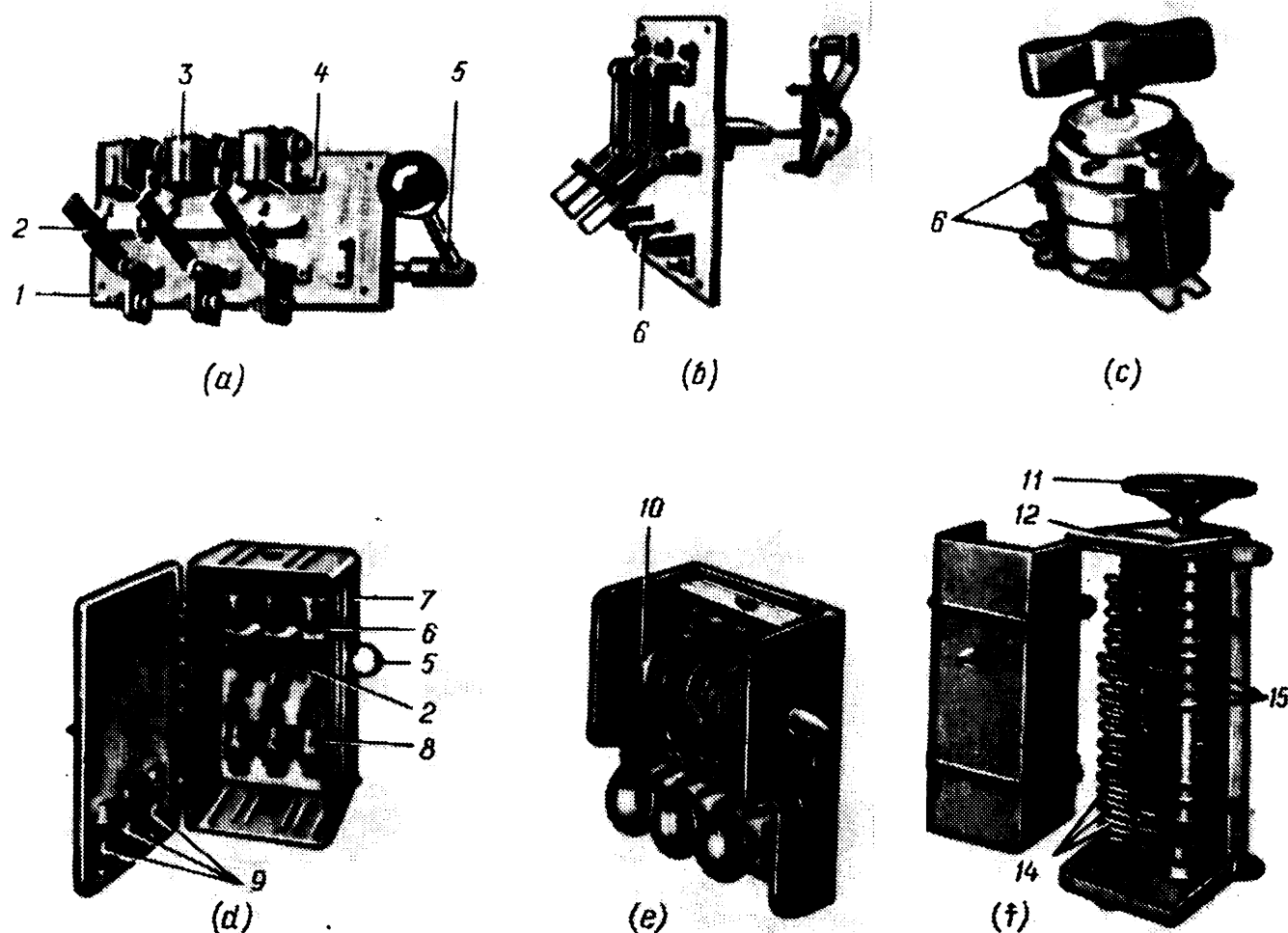


Fig. 129. Non-automatic circuit-opening devices

a—three-pole knife switch; *b*—change-over switch; *c*—packet switch; *d*—starting gear box; *e*—drum switch; *f*—controller; 1—insulating plate; 2—contact blade; 3—arc-control chamber; 4—stationary contact support; 5—handle; 6—stationary contact; 7—box body; 8—fuse; 9—spare set of fuses; 10—drum carrying movable contacts; 11—hand-wheel; 12—cast-iron plate; 13—stationary contacts mounting rod; 14—cam contacts; 15—segmental sliding contacts

8.6.2. Automatic Circuit-Opening Devices

The three-pole a.c. contactor, type KT (Fig. 130a) is designed for the remote and automatic control of electric circuits and motors. It consists of contacts, an electro-magnet, and arc-control devices.

The contactor comprises three power contacts composed of movable contact members 4 and stationary contact members 5 (Fig. 130c) which function to open the motor circuit, and also auxiliary contacts 3 and 11. Each power contact presenting one pole of the three-pole contactor is enclosed in an arc-control chamber 6. The arc-control device is a chamber built up of two asbestos end plates joined together and accommodating a grid composed of copper-clad steel plates 14. The

plates are arranged perpendicular to the arc length so that an electric arc developing between the contact members is split into short arcs across the grid, which cool down as they come in contact with the plates and rapidly go out.

The electromagnet (Fig. 130*b*) functions to open and close the power contacts. It consists of a yoke 12 with a core 7, an armature 8 mounted on a plate 10, a coil 9, a shading coil 13, and fastenings.

The contactor is controlled as follows. As voltage is applied to the coil 9, the core 7 attracts the armature, and the latter, while turning together with the shaft 2,

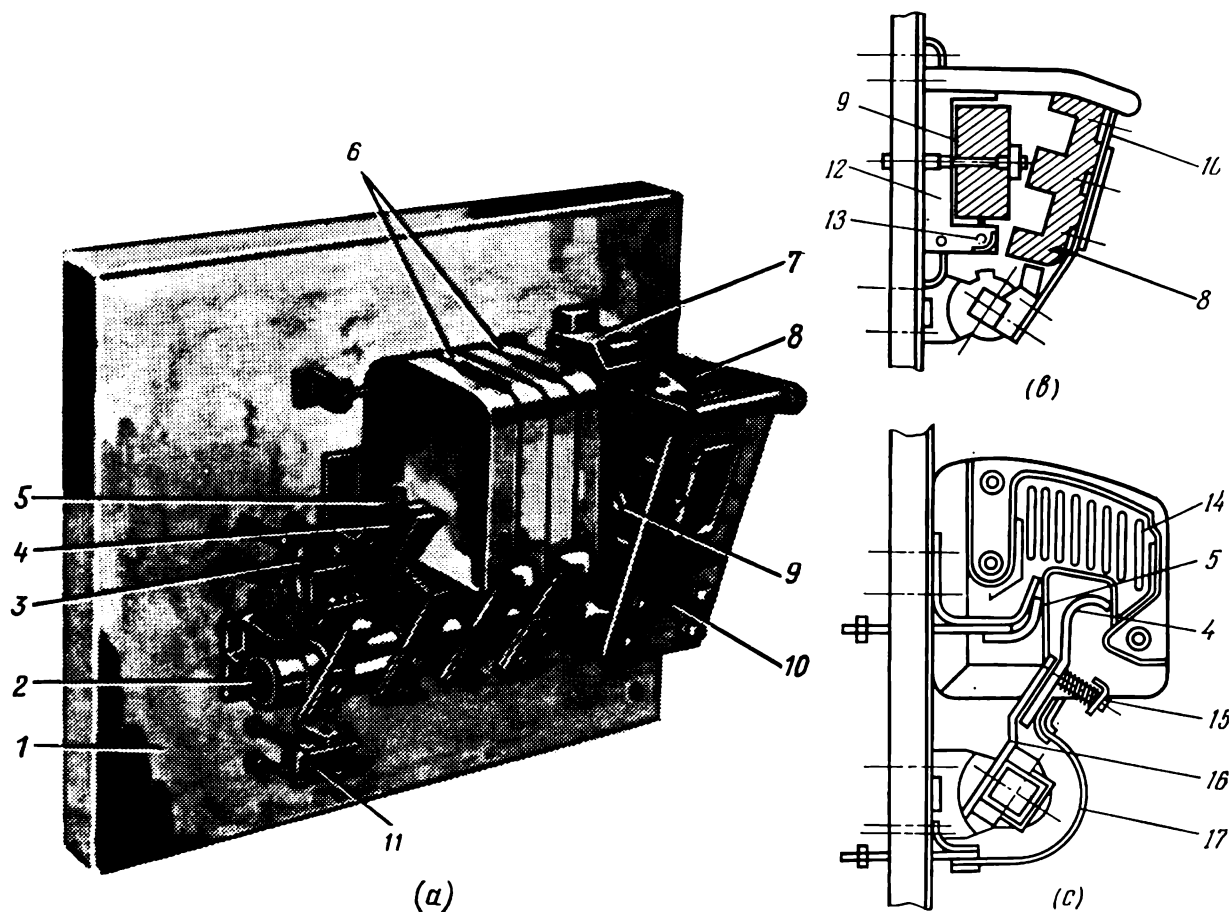


Fig. 130. Three-pole a.c. 400-A contactor RT

a—general view (with arc-control chamber removed from the first pole); *b*—electromagnet; *c*—contacts and arc-control chamber; 1—insulating board (panel); 2—shaft mounting movable contacts and armature; 3—auxiliary make contacts; 4—movable power contact; 5—stationary power contact; 6—arc-control chambers; 7—electromagnet core; 8—armature; 9—electromagnet coil; 10—armature mounting plate (holder); 11—auxiliary break contacts; 12—core yoke; 13—shading coil; 14—arc-control chamber plates; 15—contact spring; 16—movable contact holder; 17—flexible joint

forces the movable contacts mounted on the same shaft to the stationary members and holds them tight in the closed position. A copper shading coil 13 fitted in a groove in the butt end of the armature 8 eliminates chattering and prevents spontaneous opening of the contactor at the moment the current supplied to the coil passes zero. The current produced in the shading coil, like in a secondary winding of a transformer, is shifted in phase relative to that flowing in the coil

and creates, in its turn, a flux through the armature which holds the armature picked up when the coil current passes zero.

Opening the coil circuit demagnetizes the core, which does not hold the armature any longer, with the result that the movable contact members drop out by

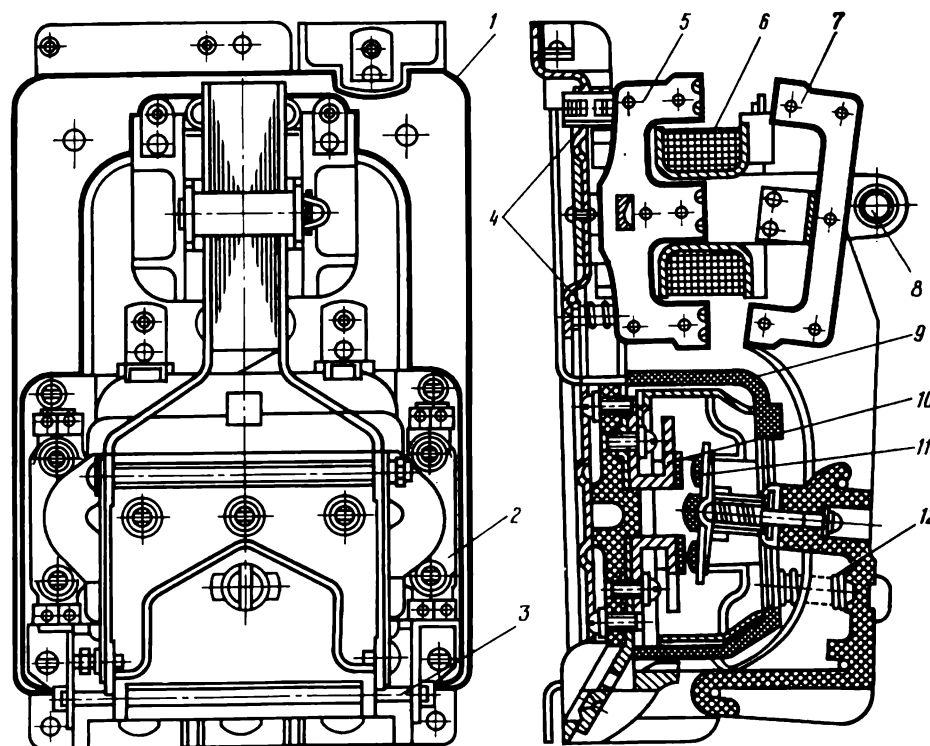


Fig. 131. Magnetic starter contactor

1—base; 2—auxiliary contacts; 3—armature axis; 4—damping springs; 5—core; 6—coil; 7—armature; 8—stop; 9—insulating chamber; 10—stationary contact; 11—movable contact; 12—armature reset spring

gravity and under the effect of the armature mass, thereby opening the motor supply circuit.

Each contactor is furnished complete with a certificate which contains the schematic and wiring diagrams of the device and some instructions for its installation, wiring, debugging, and operation.

Contactors are not meant to protect the motor against overloads. This protection is afforded by a magnetic starter which is essentially a circuit-opening device incorporating a contactor and thermal relays. Magnetic starters employ the type ПА contactors (Fig. 131) which consist of a base 1 mounting a core 5 with a coil 6, an insulating chamber 9 accommodating stationary contact members 10, a stop 8, a moving system comprising an armature 7 and movable contact members 11. The core rests on damping springs 4 which damp out the armature blows against the core at the moment the magnetic system is closed. The armature is reset to the extreme off-position by means of the spring 12. The armature travel, while it turns about the axis 3, is limited by the stop. As the armature picks up, the movable contact members come in contact with the stationary members. At the same time auxiliary contacts 2 close, some of them shorting out the "stop" button

so that it could be released after the motor is started and some completing the respective protective circuits.

The thermal relay of the magnetic starter is an arrangement of two joined bimetallic strips made of alloys having different temperature coefficients of linear expansion and placed near heating elements made of nichrome or ferrochromium alloy.

An overload current flowing through the bimetallic element heats the latter, which bends up due to the difference in the coefficients of linear expansion of its components and actuates the latch of the starting gear. The relay contacts open in the hold-in circuit, the de-energized coil does not hold the movable contact members any longer so that they drop out by gravity and under the action of the reset spring 12, thereby setting the contactor in the off-position. The starting gear is reset and its contacts are closed again by means of the reset button after the thermal relay has cooled down.

More advanced circuit-opening devices combining control and protective properties are circuit breakers.

Most widely used in electrical equipment rated up to 1,000 V are the series AII, A-3,100, and A-2,000 circuit breakers of various modifications designed for different rated and setting currents.

The series AII three-pole circuit breakers (Fig. 132*a*) are suitable for the control of small electric motors and electric circuits carrying low load currents. Heavier currents are usually handled by the series A circuit breakers.

The A-3,100 circuit breaker (Fig. 132*b*) is provided with a plastic cover that closes the current-carrying parts of the device. The single-step contact system of the circuit breaker consists of sintered-metal clad movable and stationary contacts. The movable contacts are linked via flexible joints with the busbars of an overcurrent and a thermal release.

The movable contact holders are linked with the common insulated steel shaft via a trip-free mechanism provided with a free handle. An electric arc built up between the contact members as they break an electric circuit is suppressed within a chamber incorporating an arc-control grid composed of copper-clad steel plates.

The operating mechanism affords a momentary closure and opening of the contacts at a constant speed independent of the motion speed of the free handle. The trip-free mechanism opens the circuit controlled upon the occurrence of overload or short circuit irrespective of the position of the free handle at the moment.

Automatic opening of the circuit breaker is afforded by a special arrangement, a release, mounted in a separate plastic case. The release consists of a thermal element and an electromagnetic element installed in each pole of the circuit breaker. The thermal element contains a directly or indirectly heated bimetallic strip. The strip bends up when it passes overload current and turns the disconnecting rod of the operating mechanism. As the rod turns, the circuit breaker opens irrespective of whether overload has occurred in one or more phases. The heavier the overload current, the faster opens the circuit breaker. The circuit breaker does not respond to 110 per cent overload current; at 130 to 140 per cent overload it opens within an hour, and at 200 per cent overload within 20 to 100 s at an ambient tem-

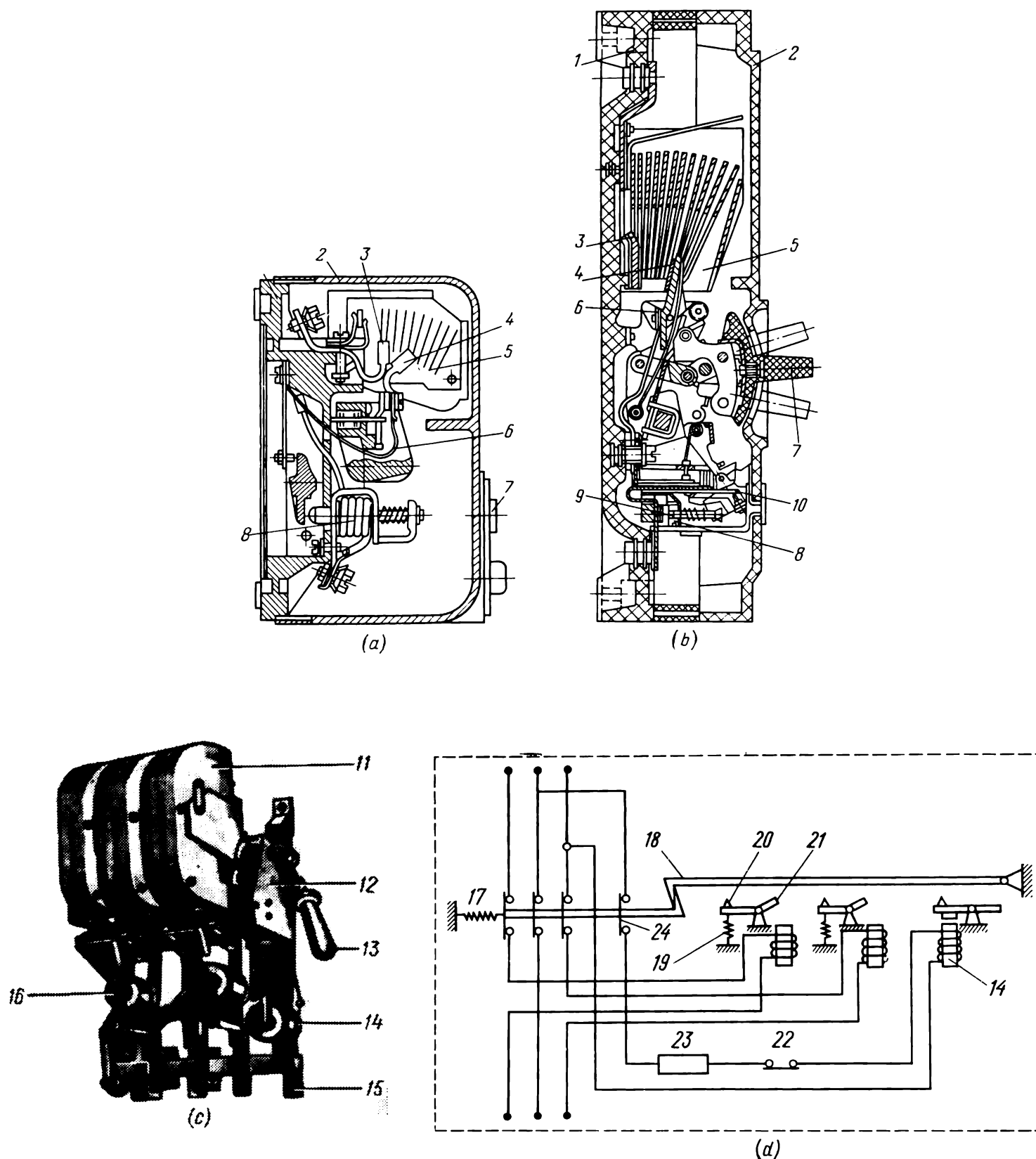


Fig. 132. Three-pole circuit breakers

a—AII-50; *b*—A-3,100; *c*—A-2,000; *d*—schematic diagram of A-2,000 circuit breaker; 1—base; 2—cover; 3—stationary contact; 4—movable contact; 5—arc-control chamber plates; 6—flexible joint; 7—free handle; 8—electromagnetic release; 9—thermal release; 10—electromagnetic release spring; 11—arc-control chamber; 12—trip-free mechanism; 13—free handle; 14—undervoltage relay coil; 15—terminals; 16—overcurrent relay coil; 17—disconnecting spring; 18—latch; 19—relay spring; 20—striker; 21—relay armature; 22—remote-control button; 23—series resistor; 24—auxiliary contacts

perature of 25°C depending on the type of the circuit breaker. It recloses after the thermal element has cooled down, which takes 3 or 4 minutes.

The thermal element does not afford protection against short-circuit currents. This function is performed by the electromagnetic element of the release. This element comprises a return spring and a magnetic core. Fitted inside the core is a working current busbar. At normal currents the spring retains the armature in a loose state. Upon the occurrence of a short circuit a strong magnetic field is set up through the core that forces the armature to change its position and to turn the disconnecting rod. In the action, the circuit breaker opens instantaneously irrespective of the number of phases shorted out.

The release of each circuit breaker is adjusted to a definite setting current and a seal is applied to it. The setting current of the release also determines the rated current of the circuit breaker operating in conjunction with the release.

The release cover shall never be removed during installation, nor shall it be readjusted. The circuit breaker must never be used to handle working currents other than those specified, otherwise it will not afford the desired protection.

The series A-3,100 circuit breakers are manufactured to handle currents from 50 to 600 A.

The series A-2,000 universal three-pole circuit breaker is used for starting high-power electric motors and for switching and protecting electric circuits carrying heavy load currents. This circuit breaker (Fig. 132c) is fitted with two overcurrent electromagnetic releases and an undervoltage release. The overcurrent releases of the circuit breaker may be provided with time delay units that function to afford a time delay in opening the circuit breaker upon the operation of the release. This time delay is required to prevent opening of the circuit breaker upon the occurrence of short-time overloads (as in the case of starting large motors).

The circuit breaker is held in the on-position by a latch 18 (Fig. 132d). At overloads or short circuits the current relay coil of the overcurrent electromagnetic release opposes the tension of the spring 19 and attracts the armature 21. In the action, the striker 20 of the armature 21 pushes the latch 18 and the disconnecting spring 17 opens the breaker contacts, thereby setting it in the off-position.

The circuit breaker may likewise be employed to open a circuit upon an abnormal decrease of voltage. As this takes place, the current flowing in the relay coil 14 of the under-voltage release decreases, the relay armature goes away from the coil core under the action of the spring, its striker releases the latch 18 and opens the circuit breaker. The circuit of the coil 14 is completed through auxiliary contacts 24 on the circuit breaker shaft, series resistor 23, and remote-control off-button 22.

The circuit breaker is opened and closed manually by means of a free handle or a lever-type operating mechanism. Where a remote control is desired, the circuit breakers are furnished with electromagnetic or motor-actuated operating mechanisms.

8.7. Installation of Circuit-Opening Devices

Knife switches are mounted on insulating boards or panels made of mechanically strong heat-resistant materials. The panel of the desired size and thickness is marked out by means of a template or by reference to the dimensions of the knife

switch to be mounted on it. The holes of appropriate diameters are drilled in the panel. To make the bolts that secure the insulating boards or panels to a framework flush with the surfaces, appropriate recesses shall be provided in the boards or panels.

Knife switches for currents not exceeding 300 A incorporated in the switchgear installations rated up to 220 V may be mounted on the front of the switchboard. When turning on the knife switch, its blades must enter the contact jaws with a certain degree of interference.

Single aluminium conductors are connected to knife switches by means of washers. The ends of single copper conductors are coiled up into a loop which is fitted on a binding post. The coil lay must follow the direction in which the terminal nut is turned in, otherwise the loop may straighten up. Stranded aluminium and copper conductors are terminated with lugs for the connection to the binding posts of the knife switch. The contacting surfaces of the blades and jaws shall not be lubricated.

The equipment of outgoing lines may be mounted on a single panel in two or three rows depending on the power rating, size, and quantity of devices to be installed.

With circuit breakers and fuses mounted on a board, no other devices or current-carrying parts shall be located above them.

Open fuses shall be arranged so that hot gases and vapours of the fuse-link molten metal could not reach adjacent elements mounted on the same switchboard when the fuse blows out; the same requirement concerns arc-control chambers of circuit breakers. It is good practice to install these parts at a distance of at least 200 mm in the horizontal plane and at least 400 mm in the vertical plane from the other circuit components.

The blades of knife switches and circuit breakers must not be energized when in the off-position.

The circuit breaker must be installed so as to ensure easy access to its parts for examination and repairs. The circuit breaker shall be mounted with its arc-control chambers removed.

The upper terminals of the circuit breaker are used for the connection of supply leads and the lower ones for the connection of conductors running to power consumers.

The baseplate mounting the circuit breaker shall be levelled off to exclude bending stresses in the breaker plate or framework as it is screwed in. The circuit breaker proper must be installed with its framework or plate set vertically. The clearance between the lever-type operating mechanism plate and the base on the switchboard must be minimum 250 mm.

After the circuit breaker is mounted in position, its arc-control chambers must be installed in place. The movable contacts of the circuit breaker must not brush against the chamber walls.

Before mounting a drum controller, its cover must be removed, the contacts cleaned of dust and slushing grease, and all its elements thoroughly examined. The contacts are checked for tight fitting between the movable and fixed members, and if the contact pressure is insufficient, the locking bolt of the hold-down ring

is turned out, the stationary contact is pressed to the movable member, and the hold-down ring is fixed again with the locking bolt. If the low contact pressure is the result of a slack or damage of the cam holder spring, the faulty spring must be replaced with a spare one supplied as standard equipment of the controller.

Prior to installing the controller, its contacts must be checked for correct positioning on all the fixed points by turning the controller handwheel; it is also required to check all the insulating parts of the controller for condition. If faulty parts are revealed, they must be replaced with new ones. The controller is fixed with bolts and nuts on a foundation plate or a metal structure and then checked for proper wiring and reliable operation. Wire leads shall be connected to the controller terminals with reference to the pertinent certificate, service manual, and the wiring diagram attached to the underside of its case.

Contactors and magnetic starters must be thoroughly examined before installation so as to check them for missing standard items and fastenings, and for troubles that may interfere with their installation. To this end:

(a) the device is cleaned of dust and dirt accumulated in the course of transit and storage;

(b) the magnetic system is unwedged, cleaned of slushing grease, the polished surfaces are flushed in pure petrol and wiped with dry waste;

(c) the armature is pushed by hand to check its motion, proper sequence of movable and auxiliary contacts, and proper fitting of the armature to the core (the armature must bear on the core with at least 70 per cent of its surface; the size of the contacting surface is determined by traces left on a sheet of paper inserted together with carbon paper between the armature and the core);

(d) the reset springs of the moving system are checked for condition and operation (the armature must easily return to the extreme initial position);

(e) the circuit-to-circuit and circuit-to-earth insulation resistances of the current-carrying parts are checked with a megger; if the insulation resistance is lower than 1 M Ω , the device shall be dried out;

(f) the arc control devices and chambers are checked for condition; if cracks or chips are detected, the chambers must be replaced with new ones; the coil shall be checked for proper mounting on the core, for the condition of its insulation and for turn-to-turn fault;

(g) all the fastenings are checked for tightness, and thermal relays for condition.

The contacts of newly installed devices must be checked for proper separation, follow-through, and pressure.

Contact separation is the closest distance from the stationary to the movable contact members when they are open (dimension *A* on Fig. 133a).

Contact follow-through is a distance that might be covered by the movable contact after full closure if the fixed member were removed. Since this parameter cannot practically be determined, the check is restricted to determining the gap between the plate 4 mounting the movable contact and the bar 5 of the contact holder in the closed position of the contacts (Fig. 133b).

Separation (gap) of movable and stationary contacts in an open position and their follow-through in a closed position are very important characteristics. The

specified separation of contacts ensures a normal arc suppression while the adequate follow-through provides for a reliable opening of contacts.

A likewise important parameter is the initial and final contact pressure.

Initial contact pressure is a pressure afforded by the contact spring at the point of initial contact. Insufficient initial contact pressure may cause fusion of contacts, while excessive initial pressure may lead to unreliable operation of the contactor.

The initial contact pressure is checked with the contacts open (Fig. 133a). The line of contact is marked on the movable member in advance. A strip of thin paper

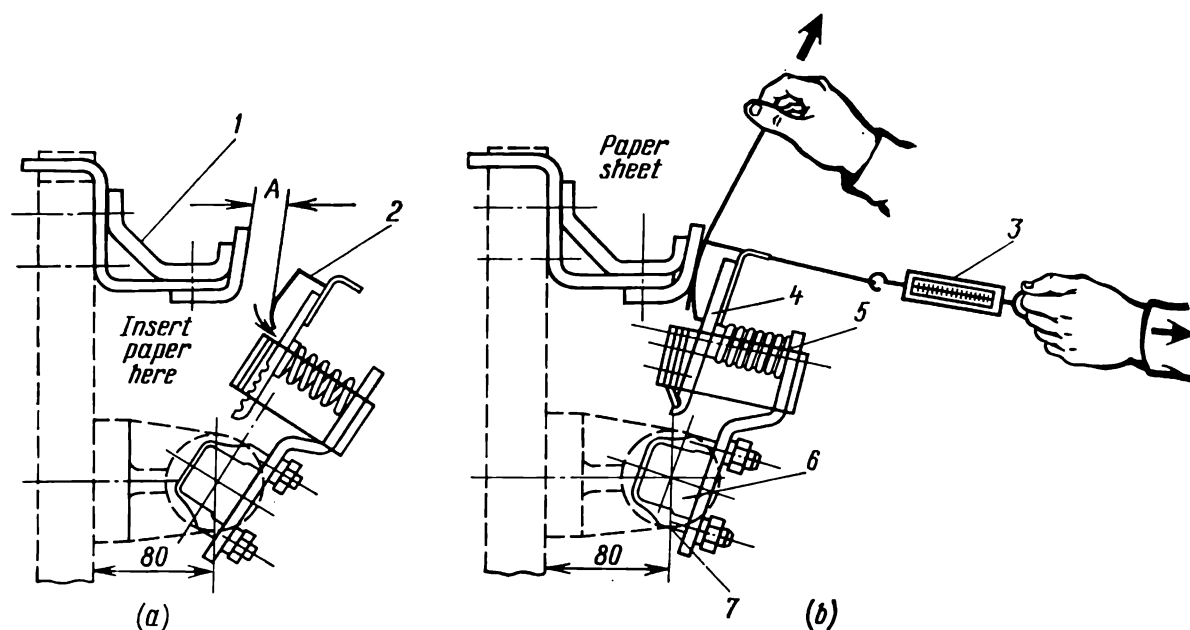


Fig. 133. Adjustment of contact separation, follow-through, and final pressure

a—determination of contact separation and initial contact pressure with the magnetic system open; *b*—determination of contact follow-through and final contact pressure with the magnetic system closed; 1—stationary contact; 2—movable contact; 3—dynamometer; 4—movable contact plate; 5—contact holder bar; 6—shaft carrying movable contacts; 7—clip fastening the contact holder bar to the shaft

is fitted between the movable contact and its mounting plate. The hook of a dynamometer is inserted into the hole of the movable contact and pulled until the strip of paper is easily drawn out by hand. The dynamometer readings at the moment indicate the initial contact pressure. While measuring this parameter, it is essential to see to it that the line of pressure is normal to the contacting area, otherwise the dynamometer may give inadequate readings. If the movable contact has no hole to receive the dynamometer hook, the latter can be attached to a loop of capron or herringbone tape applied along the line of contact.

Final contact pressure is a pressure afforded by the contact spring when the contactor is fully closed.

The final contact pressure is checked while the contactor is fully closed, proceeding in the same manner as in checking the initial contact pressure, the only difference being that the strip of paper is inserted between the stationary and the movable contacts (Fig. 133b).

The contact pressure is adjusted by changing the position of the movable contact holder bar; the bar position is adjusted by tightening up or releasing the nuts fixing the holders 5 with clips 7 to the shaft 6.

For the data on the adjustment of contact separation, follow-through, and pressure, reference shall be made to pertinent certificates.

After a device is installed in position and fully adjusted, it shall be given ten trial on-operations by hand. Sticking of moving parts, incorrect fitting of contacts, and other defects interfering with the normal operation of the device shall not be admitted.

It is also required to check the auxiliary contacts for proper operation and the arc-control device for condition. With the device in the on-position, the gap between the armature and the core must be small enough to pass a 0.05 mm feeler gauge to a depth not greater than 5 to 7 mm.

Prior to placing the device in operation, it must be checked for the ability of performing at least five on/off cycles by applying voltage to its operating coil, with the power circuit de-energized.

It may happen that during the trial on/off cycles the device produces a humming noise and closes incompletely or fails to close at all. The former defect may be caused by sticking in the moving system and the latter, by excessive pressure of the contact or reset springs. These defects must be eliminated and the device tested again.

The same procedure and the instructions given in pertinent service manuals shall be used in mounting most circuit breakers and miscellaneous starting devices similar to contactors and magnetic starters in the mechanical design of their contact systems and in the principle of operation.

Review Questions

1. Describe the construction of the type IIIA busway.
2. Describe successive stages in the installation of the IIIA busway.
3. Describe the construction and mechanical design of a squirrel-cage motor and name the features distinguishing it from a slip-ring motor.
4. Describe methods of vertical alignment of shafts joined by half-couplings when installing a motor.
5. What circuit-opening devices are called non-automatic and why?
6. Describe the construction of a three-pole contactor.
7. Give the definitions for contact separation and contact pressure and show how they can be determined.
8. Describe the installation procedure of starting gear.
9. What safety precautions must be observed when mounting electric motors, starting and control gear?

Installation and Wiring of Substation Electrical Equipment

A substation of an industrial plant is an assembly of equipment designed to receive energy from a home power plant or a power system, convert it to a form suitable for local distribution, and distribute the energy to feeders.

Substations used to supply with power most modern industrial plants are unit-type installations set up in accordance with typical switching circuit arrangements and built to afford a certain degree of versatility. Versatility of a unit substation consists in that such a substation can be used to feed various industrial consumers differing in the character and technology of processing and similar in basic electrical load characteristics, such as current system (a.c. or d.c.), voltage, power, etc.

Unit substations are preassembled and wired by specialized factories and delivered to the installation site in a partly or fully assembled condition.

In practice, however, individually assembled substations are often employed by industrial plants. They have unique switching circuit arrangements, make-up, quantity and characteristics of pieces of electrical equipment incorporated.

These substations are built to special projects and are referred to as unique substations. They often incorporate separate unit substations.

This Chapter deals with the installation of electrical equipment in both unit and unique substations.

Substations usually incorporate the following basic electrical equipment: switchgear buses, isolators, power-isolating switches and oil circuit breakers with operating mechanisms, fuses, power and instrument transformers, surge diverters, and reactors.

9.1. Installation of Switchgear Buses

Switchgear buses are installed in two stages. The first stage includes operations concerned with the installation of insulators and the second stage, with the attachment of buses to them.

9.1.1. Installation of Insulators

Insulators are designed to support current-carrying parts and to insulate them from each other and from various metal parts of electrical equipment which are normally dead. Substation insulators are usually made of porcelain. Porcelain

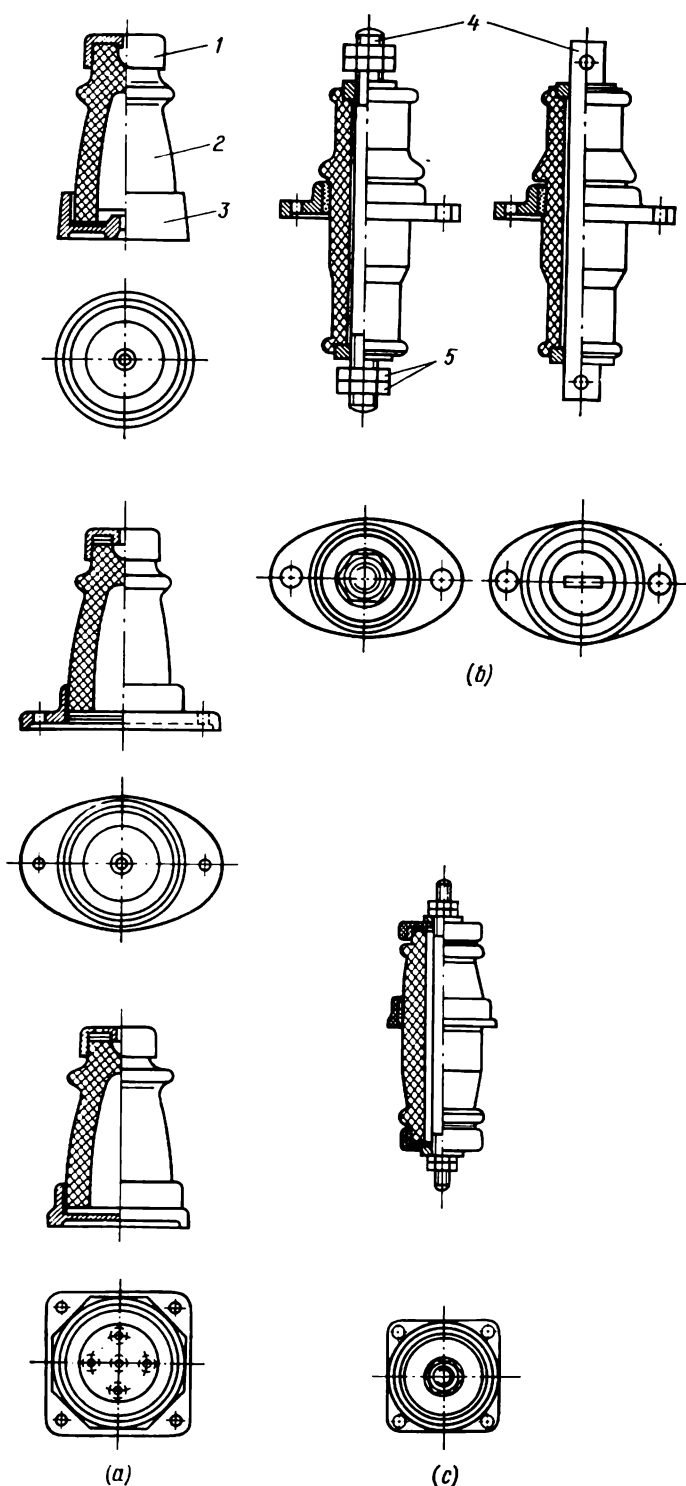


Fig. 134. Substation insulators for indoor installation rated 6 and 10 kV

a—support insulators with round, oval, and square flanges; *b*—bushings with oval flanges and round and flat current leads; *c*—bushing with square flange and round current lead; 1—cap; 2—porcelain body (insulating element); 3—flange; 4—current leads; 5—nuts

surfaces are glazed to fill all the cavities and voids and to increase moisture resistance of insulators.

Porcelain insulators bear letter designations showing some of their characteristics. So, letters O, II, and M define their application (O — support insulator, II—bushing, M—small-sized insulator); letters A, Б, В, Г, Д indicate the insulator group according to permissible mechanical load (A = 375, Б = 750, В = 1,250, Г = 2,000, and Д = 3,000 kgf). After the capital letters A, Б, В, Г, or Д stand small letters кр, ов, кв showing the shape of the insulator flange (round, oval, or square, respectively). Numerals following letter designations determine the insulator rated voltage (numerator) and current (denominator). For example, the type designation ОБкр-10/600 is decoded as follows: support insulator, group Б, round-flange, rated at 10 kV, 600 A; the type designation OMA-6 means support insulator, small-sized, group A, rated at 6 kV.

Bright support insulators and bushings meant for indoor installation are used for enclosed substations.

Substation support insulators (Fig. 134*a*) consist of a cast-iron cap 1 mounted on a porcelain body 2 that is embedded in a round, oval, or square flange 3. The porcelain body is the insulating part; the flange has one, two, or four holes through which it is bolted to a supporting structure. The caps of support insulators have threaded holes to receive bolts for fastening a current-carrying bus or a bus holder.

Bushings (Fig. 134*b, c*) are also provided with flanges and caps. The porcelain insulator body accommodates a flat or round current lead 4 secured to the switchgear bus by means of bolts or nuts 5.

Small-sized bushings without caps and flanges are employed in metalclad substation cubicles. Embedded in the bushing are fittings with threaded projecting ends for fastening to a current-carrying bus and to the supporting structure.

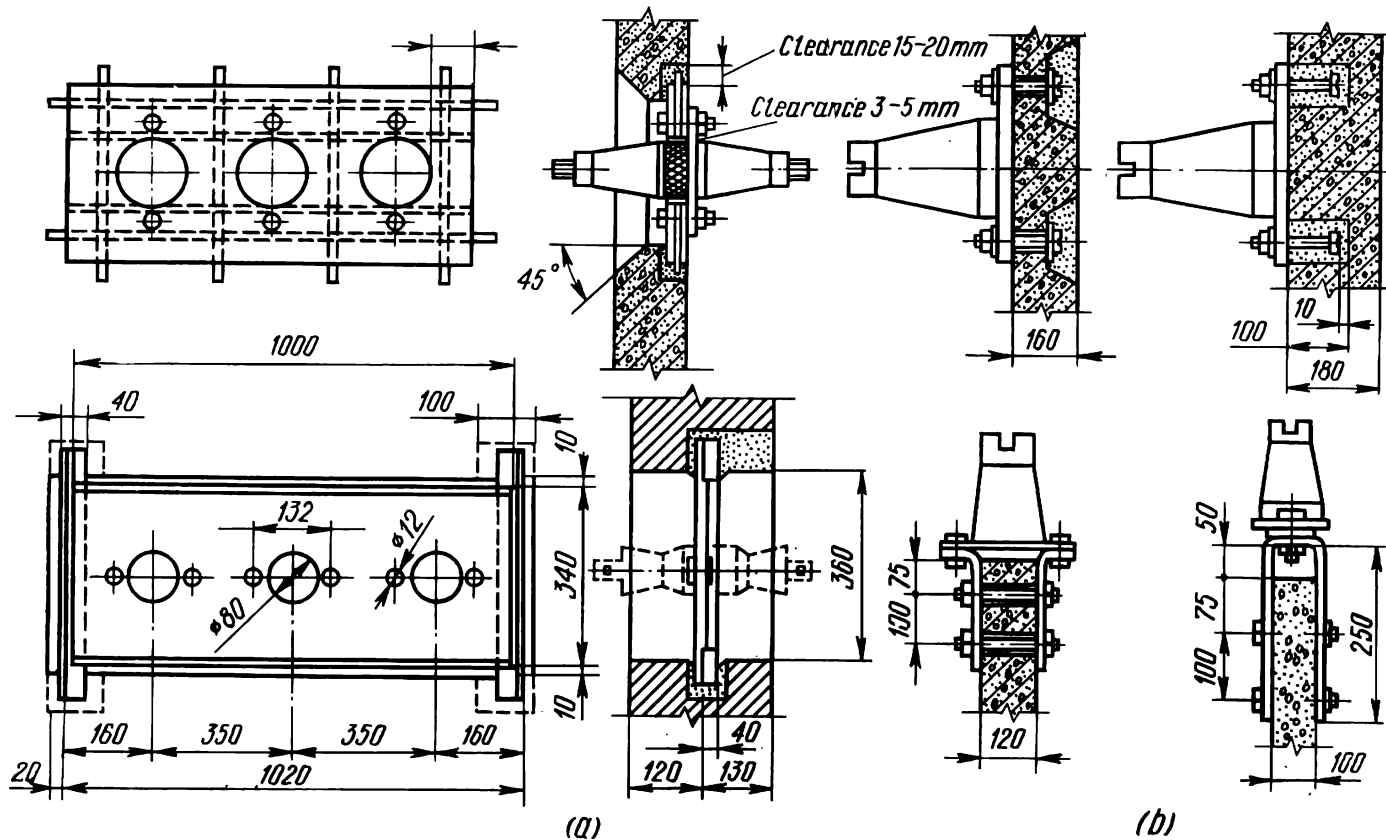


Fig. 135. Layout of insulators in an enclosed substation rated 6 and 10 kV

a—bushings; b—support insulators

Prior to mounting, the insulators must be thoroughly wiped and examined for condition. Insulators with cracks, damaged glaze, and large chipped areas must be rejected.

Prior to fixing the insulators in position, the supporting structure must be marked out to determine the centres of future holes, maintaining the design spacings between the centre lines of insulators of different phases and specified clearances from the current-carrying parts to the walls and earthed structures. For marking out, use shall be made of hard templates and straightedges. Holes are drilled in the marked-out points with the aid of electric drills. Recesses are usually made by builders and checked on site for proper dimensions and readiness to receive insulators.

The flange portion to connect the earthing bus must be cleaned with a steel brush to afford a reliable contact between the joined parts. The base of the support insulator flange and the contacting surface of the metal structure to be earthed must be also cleaned off. Support insulators must be arranged vertically or inclined through not more than 45 deg from the vertical (Fig. 135a, b).

9.1.2. Installation of Buses

Aluminium or copper strips are used as buses of enclosed substations rated 6 and 10 kV.

The installation procedure consists in the preparation of bus lengths, their finishing, attachment to insulators, jointing of separate buses together, connection to devices, and mounting of expansion devices.

The buses are prepared at special workshops with reference to drawings. Rectangular buses are bent flat or on edge in bus-bending machines. In the absence of such a machine and in case a small quantity of buses measuring up to 60×6 mm must be bent, this operation can be made manually with the aid of a template. To this end, the bus to be bent must be preheated to a temperature of up to 250°C (for aluminium) and 400°C (for copper).

The finishing procedure consists in drilling holes for fastening the buses on insulators, bolting them together and preparing the bus surfaces for welding. For drilling holes the buses are clamped in jigs to ensure accurate arrangement of holes. The bus surfaces to be bolted together are treated in a mill or, if this is not available, by means of a bastard file or a steel brush to obtain the desired roughness for better contact of the joint. Aluminium buses must be treated under a petroleum jelly coat.

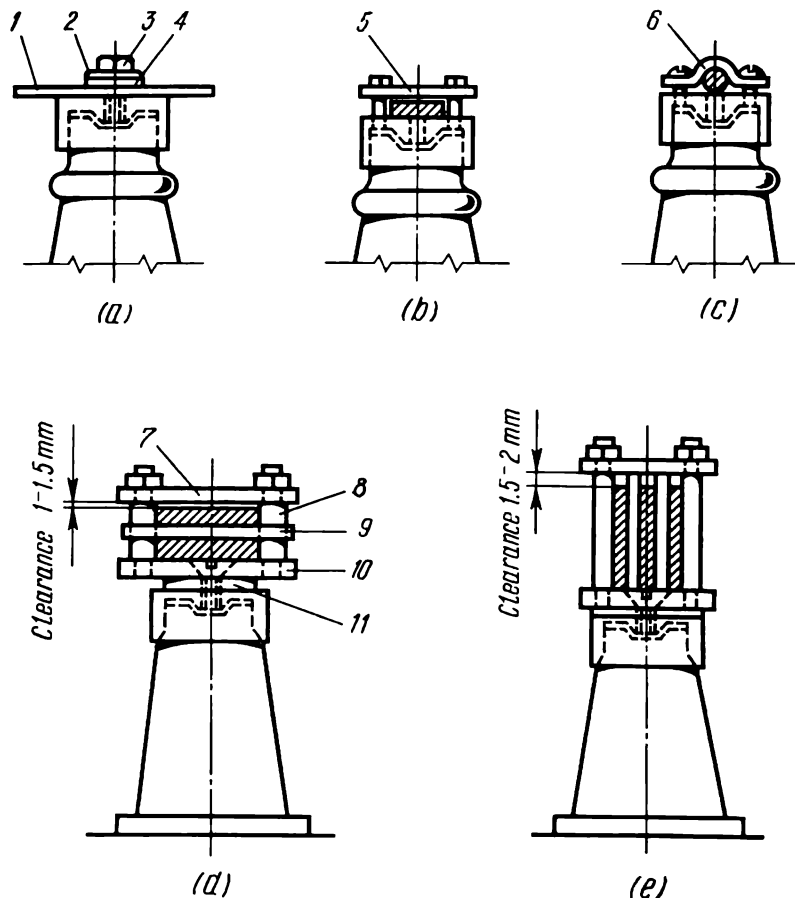


Fig. 136. Methods of switchgear bus jointing

a—single-strip buses, by means of a flat bolt; *b*—single-strip buses, by means of flat bolts and a plate; *c*—round buses, on insulator head, by means of a clamp; *d*—multistrip buses bent flat, in bus holders; *e*—multistrip buses bent on edge, in bus holders; 1—bus; 2—spring washer; 3—bolt; 4—normal steel washer; 5—steel plate; 6—steel clamp; 7—top nonmagnetic plate; 8—stud; 9—steel insert; 10—lower plate; 11—pressboard gasket

The bus ends to be welded together must be mitred on half of their thickness.

The buses are secured to insulators by means of a number of methods (Fig. 136). Single-strip buses, for example, are secured directly to the insulator cap by means of bolts (Fig. 136*a*), plates (Fig. 136*b*), or clamps (Fig. 136*c*). Where a single-strip bus is mounted flat and secured with a single bolt directly to the insulator

cap, the hole in the bus to receive the fastening bolt must have an oval shape so as to provide a certain freedom for the busbar movement due to a variation of its length as a result of heating and cooling. Multistrip buses are attached to insulators by means of bus holders (Fig. 136*d, e*) mounted on the insulator cap.

Mounting more than one bus together impairs cooling conditions for each bus. Therefore, the load on such buses must not be increased in proportion to the number of strips contained in a stack. On the other hand, each bus of the stack suffers the effect of the reversing magnetic field of adjacent strips, which increases the resistance of the strips due to the so-called proximity effect and adds to the heating temperature of the stack for the same current.

In the event of a short circuit the buses take heavy transient loads which may lead to their deformation and even to breakage of insulators unless they are reliably fixed in position. So, to avoid these drawbacks, the bus holders of multistrip

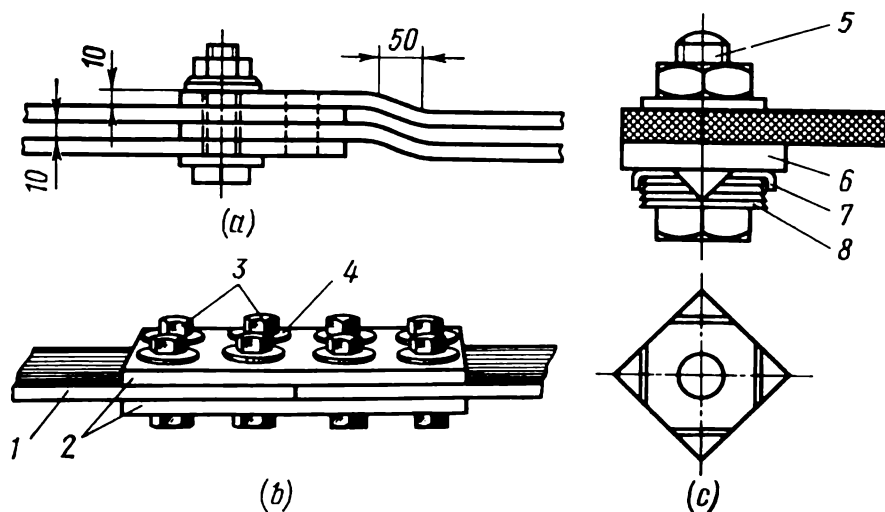


Fig. 137. Bolted joints of buses

a—lap joint; *b*—butt-to-butt joint with straps; *c*—connection to copper terminal of circuit-opening device by means of a disk spring; 1—bus; 2—straps; 3—bolts; 4—steel washer; 5—device terminal; 6—copper strip; 7—special washer; 8—disk spring

buses must be furnished with the type PIII slide blocks to improve cooling conditions for the buses and to increase the rigidity of the bus stack.

At heavy working currents (over 600 A) the bus holder parts must be arranged so as not to form a closed circuit around the buses. For this purpose, the clamping bolts or one of the bus holder spacers is made of nonmagnetic material, such as bronze.

A clearance of 1 to 1.5 mm is to be provided between the top plate of the bus holder and the buses.

Nonsplit joints of buses are usually made by welding. Split joints are bolted together. Bolted joints (Fig. 137*a, b*) are preferred where easy disassembly and reassembly are important. Buses are joined with two or more bolts. The length of the bolted joint must be equal to the double width of the buses being bolted.

Directly before jointing, aluminium buses must be cleaned once more with a steel brush under a coat of petroleum jelly. Bolts must be tightened up well home,

but not too heavily to avoid indentation of the bus material and damage to the bolt thread. The contact joint may be considered adequate if a feeler gauge, size 0.05×10 mm, goes into the split between the strips to a depth of not over 5 mm on either side. Flat leads of devices are bolted to the buses. Aluminium buses are connected to copper terminals through intermediate copper strips welded to the buses or through copper strips 6 and disk springs 8 with washers (Fig. 137c).

The terminals of leads to be connected to buses must be treated in the same way as the buses. It should be borne in mind, however, that the flat leads of some

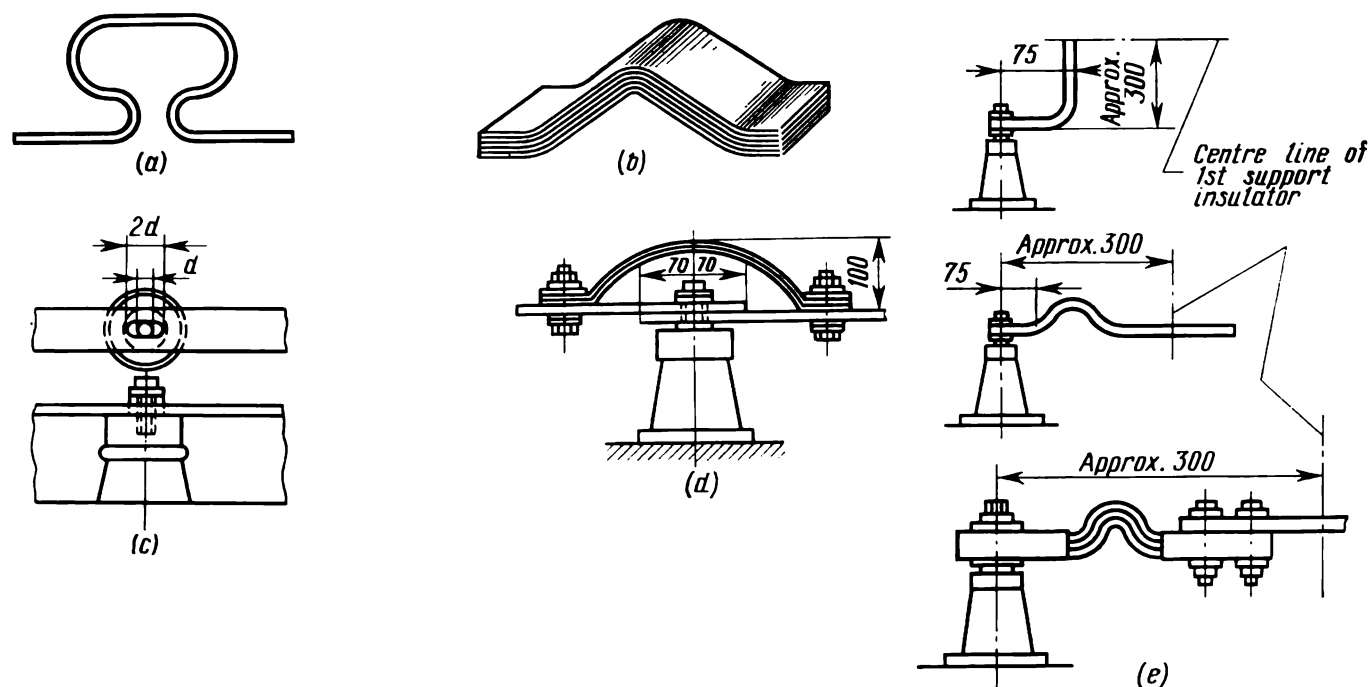


Fig. 138. Expansion devices and methods of their installation on switchgear buses

a—lyre-shaped; *b*—plate; *c*—oval recess in a bus functioning as expansion device; *d*—fixation of an expansion strip on buses; *e*—connection to device terminals

high-voltage devices (BMII-10 switches and the like) are made of an aluminium alloy and treated with corrosion-preventive materials. Such leads must never be cleaned off with a file or emery paper.

These leads must be flushed in petrol, alcohol, or any other suitable solvent before connecting them to buses.

In the course of operation the buses heat up and elongate; when further cooled down, they contract. Such a variation in the bus length may cause deformation of buses, poor contact at the joint, and even breakage of insulators, unless appropriate measures are taken to prevent this. Special expansion devices affording the protection against these abnormal conditions must be used on straight bus sections longer than 20 m.

Expansion devices for single-strip buses measuring 50×5 mm are made in the form of a bus length bent to a lyre shape (Fig. 138*a*), and for those measuring 80×6 mm and larger still they are made in the form of a stack of thin (0.3 to 0.5 mm) foil strips (Fig. 138*b*). The total sectional area of the stack of expansion strips

must be 10 to 15 per cent greater than the area of buses whose length is being compensated for. Figure 138*c, d, e* illustrates methods of compensation for the bus length and installation of expansion devices at the bus-to-bus and bus-to-lead joints.

In the construction of a substation building it may happen that the minimum clearances between the current-carrying parts and walls, floors and ceilings, other devices, etc. cannot be provided due to changes introduced in the dimensions of some building components. In mounting switchgear buses and connecting them to circuit-opening devices, care must be taken to keep within clearances specified by the project or the Regulations for Electrical Installations (Table 41).

Table 41

Minimum Clearances Between the Current-Carrying Parts and Separate Elements of Electrical Installations

Specified clearance	Dimensions, cm, for installations rated at voltages, kV		
	1-3	6	10
Between bare current-carrying parts of different phases	1	10	13
From current-carrying parts to earthed structures and building parts	6.5	9	12
From current-carrying parts to solid guards	9	12	15
From current-carrying parts to mesh guards*	16	19	22
Elevation of bare current-carrying parts at which no guard is needed	250	250	250
Between nonguarded current-carrying parts of different circuits	200	200	200
Passage clearance	190	190	190
From lower points of overhead bushing leads to ground in the absence of traffic sections**	450	450	450

* Rail bars shall never be used to guard current-carrying parts in open chambers or cubicles. Wire meshes with a mesh measuring at least 20×20 mm and at least 1.4 mm in diameter or solid guards will be normal.

** In the event of a shorter clearance from the wire leads to ground, the area under the bushing must be guarded.

Fully installed and connected buses are painted in standard colours, viz., yellow for phase A buses, green for phase B buses, and red for phase C buses. On the diagrams the phases are identified by letters Ж, З, and К, respectively.

In all cases, the phase B bus painted green must be arranged in the middle while phases A and C painted yellow and red, respectively, must be placed on both ends of the phase B bus, depending on the construction of the busbar arrangement.

Identification colours of buses must correspond to the phase sequence of transformers and feeders. Moisture-resistant enamel paints shall be used for painting the buses.

Prior to applying enamel paint, the buses must be wiped with clean rags moistened with acetone. Single-strip buses are painted on all sides. Multistrip buses are coated on external surfaces only.

Enamel paint is applied with a brush in two layers, the first layer being allowed to fully dry out before the next is applied.

Identification colouring of buses facilitates phasing-out of devices connected to them and makes it easy for the attending personnel to identify them on the reference diagrams.

9.2. Installation of Isolators and Power-Isolating Switches

Isolators and power-isolating switches are oilless high-voltage circuit-opening devices.

Isolators are not fitted with arc-control devices and function only for instantaneous changing of switching circuit arrangements and for providing a visible

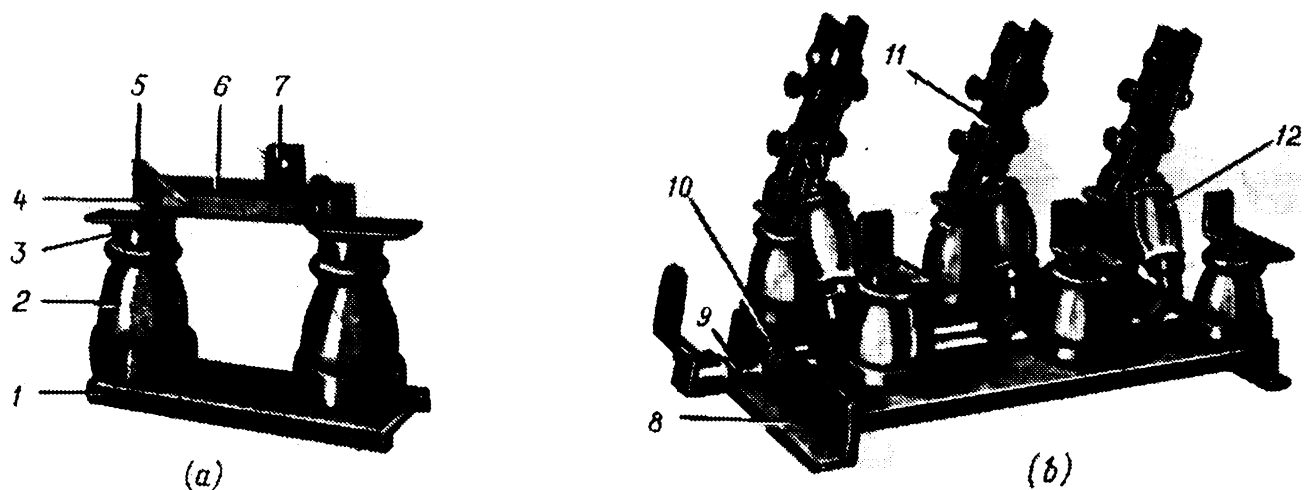


Fig. 139. High-voltage isolators for indoor installation

a—single-pole, type PBO, rated 6 kV; *b*—three-pole, type PBT, rated 10 kV; 1—base; 2—support insulator; 3—stationary contact; 4—pin; 5—stop clamp; 6—movable contact blade; 7—engaging eye for controlling the isolator; 8—mounting frame; 9—shaft; 10—stop; 11—isolator knife blade with contact springs; 12—porcelain operating rod

break in a circuit (a visible air gap between stationary and movable contacts) so as to make certain that operations can be performed on an isolated section without running a risk.

Isolators are suitable for opening the circuits of electrical equipment, lines, and separate devices carrying low currents, such as no-load current of a power transformer or charging current of a line.

Isolators may be single-pole (Fig. 139*a*) or three-pole (Fig. 139*b*). Three single-pole isolators or one three-pole isolator is used as a rule for three-phase electrical equipment.

Power-isolating switches are used to fully or partly isolate electrical equipment carrying load currents. The power-isolating switch (Fig. 140*a, b*) is constructionally identical to the indoor three-pole isolator, the difference being in the shape of contact blades and in the provision of an arc-control chamber on each pole. The arc-control chamber (Fig. 140*c, d*) consists of two plastic halves 9 and inserts

10 made of organic gas-generating material and placed between the halves. The inserts have grooves whose shape and curvature follow those of respective contact blades 4. An arc produced when the switch opens a circuit carrying heavy load currents acts on the inserts so that the latter liberate gases. These gases can escape into the atmosphere only through a narrow slit between the movable blade and

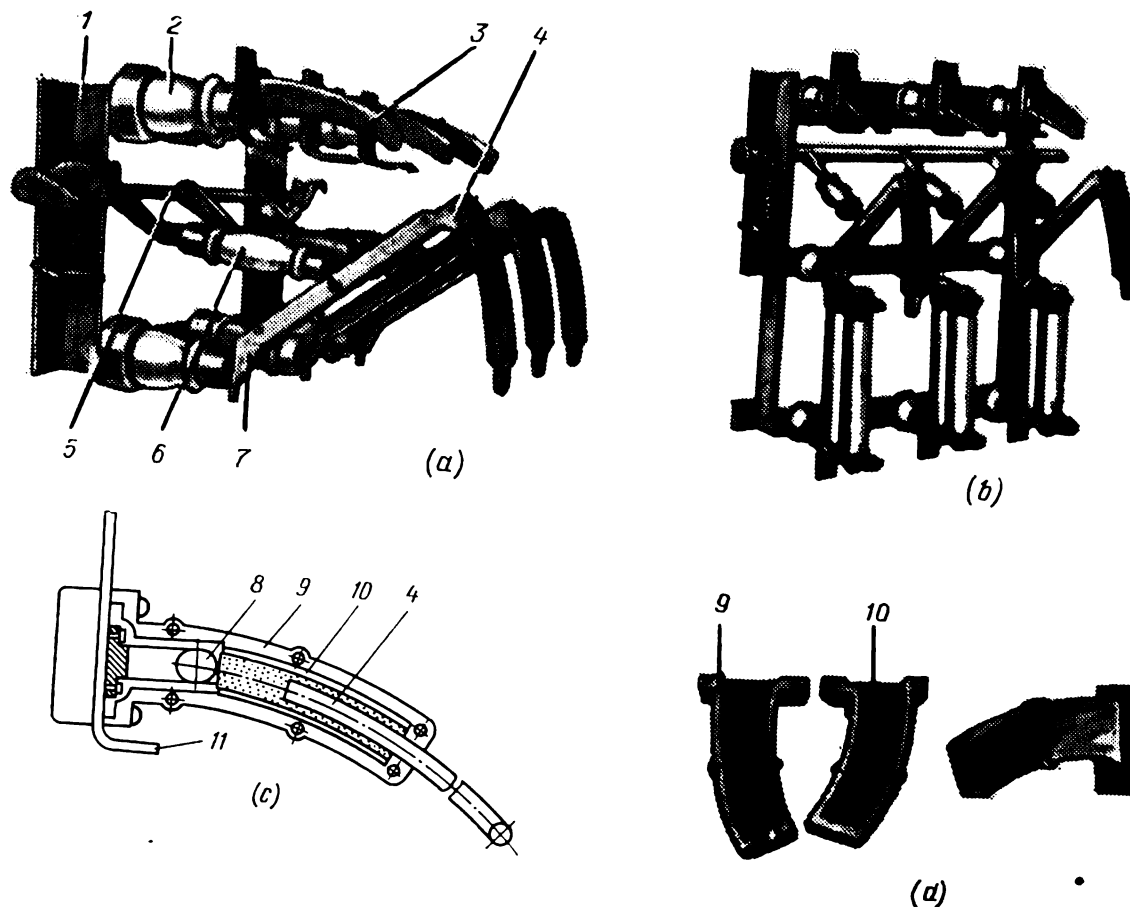


Fig. 140. Power-isolating switches rated 6 and 10 kV and their component parts
a—without fuses; b—with fuses ПР (БНП-16); c—arc-control chamber with half-chamber removed; d—chamber halves and assembled chamber; 1—frame; 2—support insulator; 3—arc-control chamber; 4—movable contact blade; 5—shaft; 6—operating rod; 7—movable contact; 8—stationary arcing contact; 9—half-chamber; 10—insert; 11—stationary power contact

the insert walls, with the result that the gas pressure within the chamber rapidly increases and aids in the rapid suppression of the arc.

The isolators and power-isolating switches are controlled by operating mechanisms. A type ПР-2 operating mechanism (Fig. 141a) is used for manual control of isolators. It consists of a front bearing 5, a handle 6 mounted on a pin 7, and a rear bearing 10. The bearings are joined together with the aid of studs 9. The handle is hinged via a lever 2 to the quadrant 3 rotating on the shaft 4 attached to the rear bearing. The lever of the isolator under control is joined via a control rod to the quadrant 3 with the aid of the lever 1. The quadrant of the ПР-2 ope-

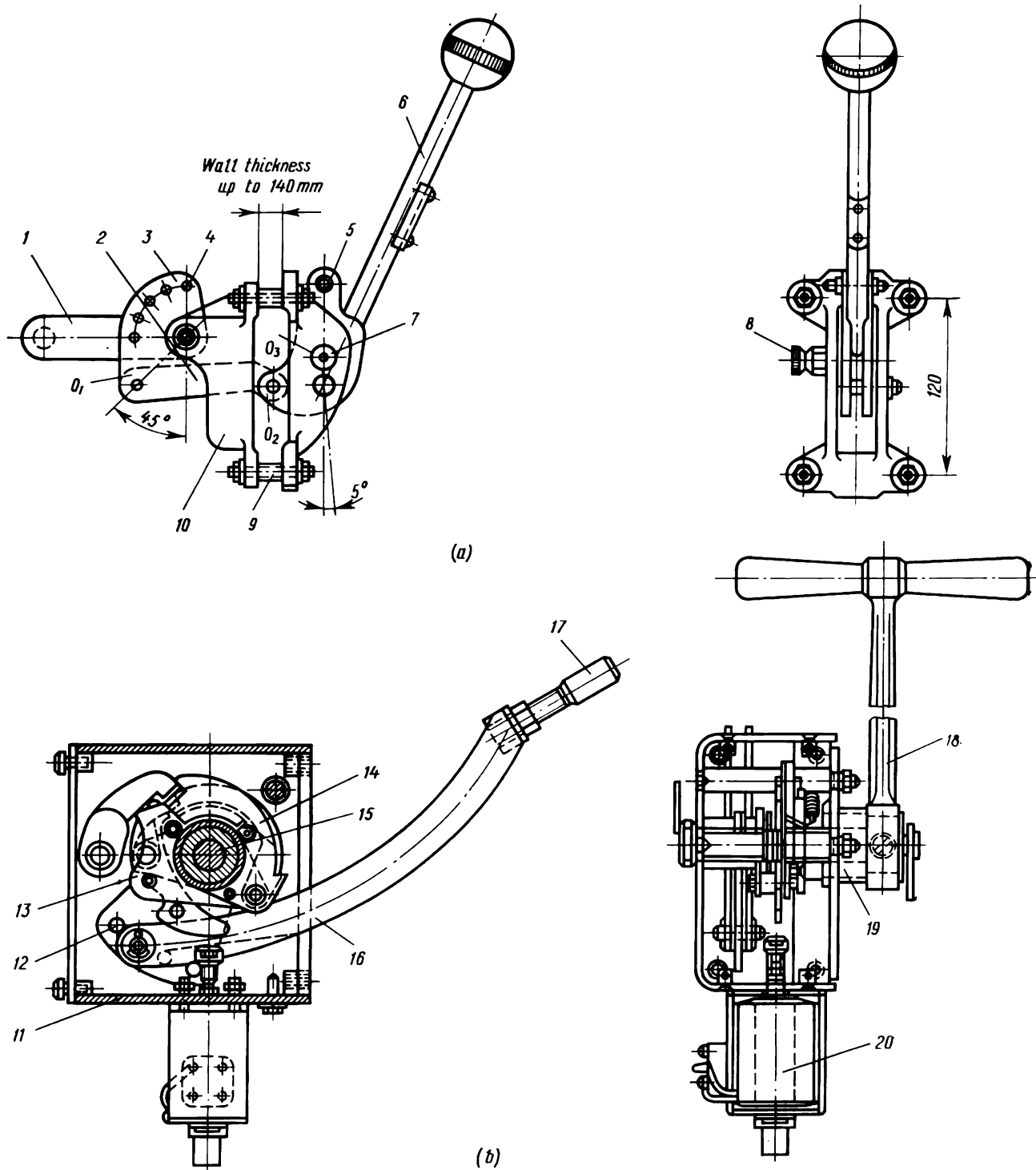


Fig. 141. Operating mechanisms of isolators and power-isolating switches

a—type ИР-2 for indoor isolators; *b*—type ИРА-12 for power-isolating switches; 1, 2, 13—levers; 3—quadrant; 4, 15—shafts; 5—front bearing; 6—handle; 7—pin; 8—retainer; 9—stud; 10—rear bearing; 11—housing; 12—quadrant lever; 14—trip-free mechanism; 16—fork; 17—operating rod; 18—making lever; 19—coupling; 20—breaking electromagnet

rating mechanism has six holes, dia 8 mm. The lever 1 is attached to one of them depending on the desired angle of turn.

The location of axes O_1 , O_2 , and O_3 in the operating mechanism determines the passage of levers through the dead zone, which makes it impossible to disconnect the isolator spontaneously.

The operating mechanism is fitted with a retainer 8 that functions to hold it in the desired positions. The retainer pin enters a hole in the operating mechanism housing; the handle has two holes, one of which is aligned with the hole in the housing when the isolator is in the on-position, and the other when it is in the off-position. As the hole in the housing is brought in alignment with one of the holes in the handle, the retainer pin enters this hole under the action of a spring and locks the handle in position. In order to change the isolator position, the retainer is pulled by its head and the handle turned through a certain angle to bring the retainer out of a latched position, whereupon the handle is turned again until the isolator fully opens or closes.

The BH-16*, BHП-16 and BHП-17* power-isolating switches are controlled by manual automatic operating mechanisms ППА-12, ППАМ-10, ППА-17, and the like. Manual automatic operating mechanisms make it possible to close the switch under control manually and to open it remotely or automatically. A remote opening and closing of power-isolating switches is afforded by operating mechanisms УГП, ППМ-10, ПС-10М, and the like. For closing a switch by means of the ППА-12 operating mechanism (Fig. 141b), its closing lever 18 must be turned manually from the bottom upwards, and for its opening from the top downwards. For the remote disconnection, use is made of a push-button provided with making contacts. The striker on the electromagnet rod moves up and hits the links of the trip-free mechanism, thereby disconnecting the operating mechanism along with the power-isolating switch.

The ППА-12 operating mechanism is accommodated in a welded housing 11. The closing lever 18 is arranged on the right-hand side of the housing. It is fitted on a sleeve 19 that rotates in the bearing on the housing cover and is linked with the trip-free mechanism 14 via a lever 13 mounted on a shaft 15. Mounted on the shaft to the left of the lever 13 is a quadrant lever 12 which is linked with an operating rod connecting the operating mechanism with the shaft of the power-isolating switch. A position indicator is provided on the right-hand butt end of the shaft, and a lever linked to the operating rod of the type KCA interlocking contacts is attached to the left-hand butt end of the shaft. The type KCA interlocking contacts are installed separately on the top of the operating mechanism.

The breaking electromagnet 20 is located on the bottom of the housing. The operating rod 17 is joined to the quadrant lever 12 through a fork 16 screwed onto the tapped pin of the operating rod.

For installing an isolator and an operating mechanism, proceed as follows:

* The BHП-16 power-isolating switch differs from the BH-16 type by a set of type ПК fuses, and the BHП-17 switch differs from the BHП-16 type by a lever system that actuates the disconnecting gear in the event a fuse link in any of the three fuses blows out.

(a) mark out the locating points for the isolator metal structures using a template, a steel measuring tape, or a straightedge for the purpose;

(b) drill holes with an electric drill and secure supporting structures by means of bolts and washers;

(c) lift the isolator onto the supporting structure and fix it in position for the time being;

(d) level off the isolator by observing the axes of symmetry of the arc-control chamber and fix the isolator on the supporting structure for good;

(e) mark out and drill fastening holes for the operating mechanism and the interlocking contacts, and mount these devices in position;

(f) couple and link (through operating rods) the isolator with the operating mechanism and interlocking contacts. The operating rod coupling the isolator with the operating mechanism can be made of a steel gas- and water-pipe, dia 18 to 25 mm, of a normal wall thickness; for fastening use shall be made of washers, lock-nuts, and cotter pins;

(g) adjust the isolator, the operating mechanism, and the interlocking contacts. The isolator blades in the closed position must enter the stationary contact jaws simultaneously, without knocks, and shall not reach the stop by 3 to 5 mm. The nonsimultaneity of closing for a three-pole isolator must not exceed 3 mm as measured between the blade and the stationary contact jaw; the fit between the blade and the jaw in closing must be such that a feeler gauge of 0.05 mm in thickness and 10 mm in width goes in through not more than 5 mm. The angle of turn (separation) of the blades must be within the values specified by manufacturer (usually 63 to 68), and is adjusted by changing the position of the levers on the isolator shaft or on the operating mechanism quadrant through shorting or elongating the operating rod, turning on or off the operating rod forks, etc. The operating mechanism and all the linkage gear must operate without sticking; the idle run of the operating mechanism handle due to clearances at the joints and elastic strain of the entire linkage shall not exceed 5 deg (see Fig. 141a). The retainer 8 of the operating mechanism must reliably lock the latter in the open and closed positions. The interlocking contacts must close and complete the off-position signalling circuits of an indoor 10-kV isolator only after the blades go away from the jaws by at least 75 per cent of their full stroke, and the on-position signalling circuits at least after the blades touch the jaws;

(h) for the final operation, earth the isolator bedframes, the operating mechanism bedplates, and the housings of the interlocking contacts.

Give 20 to 25 trial on/off cycles to the fully assembled isolator connected to the operating mechanism and the interlocking contacts. After the trial operations the isolator must not get maladjusted, the operating mechanism and the interlocking contacts must not fail.

The power-isolating switch is installed in the same manner as the insulator, the additional operation being the adjustment of contact of the blades in the arc-control chamber: the blades must enter the chambers strictly along the centre line through a depth of at least 160 mm.

Figure 142a, b, c illustrates the installation of an isolator, a power-isolating switch, and their respective operating mechanisms.

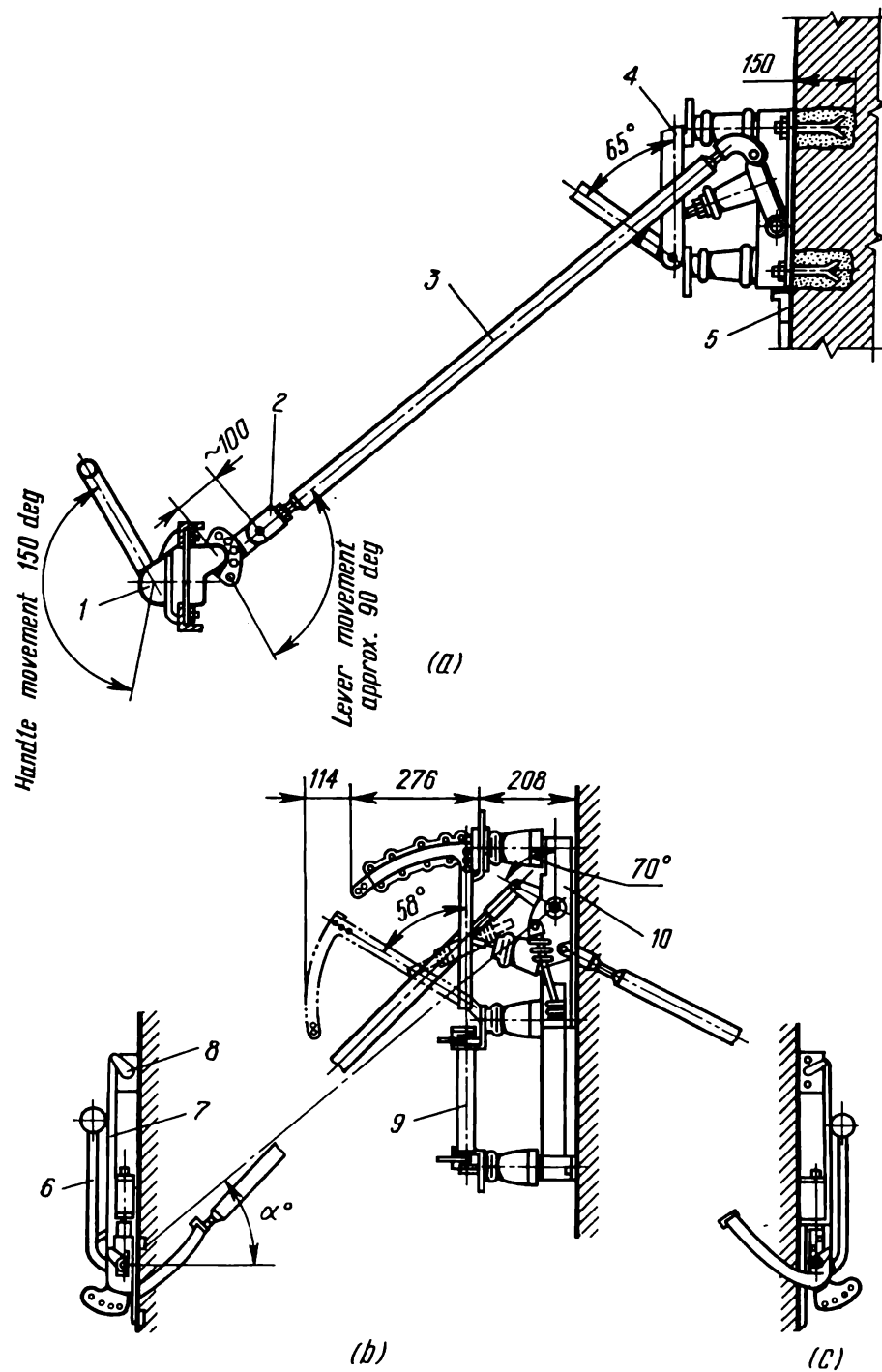


Fig. 142. Illustrations showing some methods of installation of isolators, power-isolating switches, and their operating mechanisms

a—three-pole isolator PBT rated 10 kV and operating mechanism ПП-2; *b*—power-isolating switch БНП-16 behind operating mechanism ППА; *c*—power-isolating switch БНП-16 in front of operating mechanism ППА; 1—lever-type operating mechanism ПП-2; 2—fork; 3—operating rod; 4—isolator; 5—earthing bus; 6—operating mechanism ППА; 7—operating rod linking the operating mechanism with the auxiliary contact KCA; 8—auxiliary contact KCA; 9—fuses ПК; 10—power-isolating switch

As is specified by the USSR Regulations for Electrical Installations, the insulators of newly installed isolators and power-isolating switches rated at 10 kV shall be tested by applying to them a commercial-frequency voltage of 38 kV.

With isolators and power-isolating switches using electric operating mechanisms, it is also required to check the operating voltage of the electromagnets and disconnecting gear of the operating mechanism and the operation of the isolators and switches in conjunction with the electric operating mechanisms.

9.3. Installation of Oil Circuit Breakers

Oil circuit breakers are high-voltage switching devices capable of opening and closing of high-voltage circuits under no-load and full-load conditions and upon the occurrence of short circuits.

These circuit breakers are distinguished by the design of oil tanks and the oil volume as dead-tank (bulk-oil) and live-tank (small-oil-volume) circuit breakers.

9.3.1. Installation of Dead-Tank Oil Circuit Breakers

A type BME-10 dead-tank oil circuit breaker (Fig. 143) consists of a tank with a cover, an operating mechanism, bushings, and a contact system. The cover 2 mounted on the tank 1 is secured to the latter with four steel studs. A sealing gasket 9 made of oil-resistant rubber, cork, or pressboard is fitted between the cover and the tank. The cover mounts six porcelain bushings 3, a filler hole plug 6, and an earthing bolt. At the side of the cover, there is a breaker position indicator and an exhaust pipe is brought out to discharge gases and oil escaping from the tank when heavy currents are interrupted (as in the event of overloads or short circuits). The operating mechanism is arranged under the cover and its shaft is brought outside and terminates into a fork 8 that couples the breaker with the operating mechanism. The inner surface of the tank is covered with pressboard to isolate the tank metal surfaces from the current-carrying parts.

Oil and gases liberated under the effect of electric arc (when heavy currents are handled) may explode the circuit breaker unless they are sufficiently discharged into the atmosphere. In order to prevent such an accident, the breaker is furnished with a safety device which consists of thin-walled pipe lengths 11 fitted on the studs that secure the tank to the cover. The pipes are arranged between the bottom end of the tank feet and the nut. The pipe length and wall thickness are selected so that under the effect of abnormally high pressure the pipes collapse and make it possible for the tank to slightly go down, with the result that a circular slit is formed between the tank 1 and the cover 2 for the escape of gases, thereby preventing the exposure.

The tank bottom is of a spherical shape. Welded in the centre of the bottom is a pipe union closed with a sample and drain plug 10. The tank is filled with clean transformer oil 80 per cent full so that an air space (air cushion) is left between the oil surface and the cover underside. The oil level above the contacts immersed in the tank must be at least 10 cm. All these precautions, as to the air cushion and a 10-cm oil layer above the contacts, are necessary to ensure better conditions

for arc suppression as these circuit breakers have no special arc-quenching devices. The arc is suppressed within the circuit breaker as follows.

At the moment of breaking an electric circuit by the circuit breaker contacts, an electric arc is produced at the contacts of each pole (phase). This arc has a high temperature and decomposes the surrounding oil, transforming it into gas. A gas bubble is formed about each arc, which also encloses the breaker contacts and

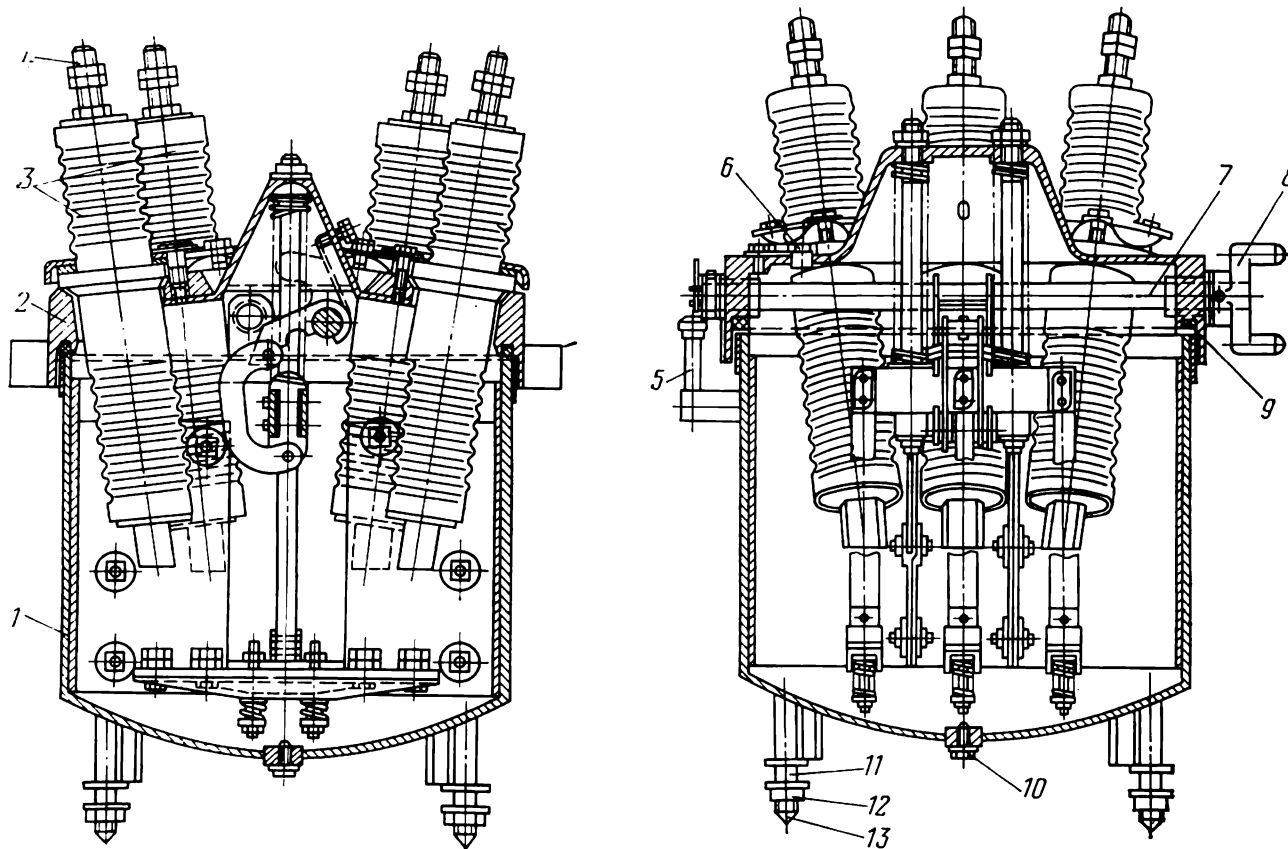


Fig. 143. Dead-tank oil circuit breaker BMB-10

1—tank; 2—cover; 3—insulators; 4—current lead; 5—oil-level indicator; 6—oil filler plug; 7—circuit breaker shaft; 8—fork for coupling with operating mechanism; 9—sealing gasket; 10—oil drain plug; 11—safety ring (thin-walled pipe length fitted on stud); 12—nut fastening the tank to the cover; 13—through stud

not only the arc. Gas formation is very intensive because every gramme of oil is transformed into a gas mixture of 1,400 to 1,500 cm³ volume composed of gases such as methane, ethylene, and hydrogen which readily explode when coming in contact with air. The gas bubble increases with the arc current and the energy in the arc gap, and pressure within the bubble rises to 10 or 12 atm.

Under the effect of pressure within the gas bubble the oil in the tank is displaced to the air cushion, thereby preventing the risk of dangerous pressure within the tank. The oil layer covering the contacts does not allow the gases to come in contact with the air filling the free space under the tank cover.

As the current passes through zero, the intensity of the arc formation abruptly goes down; at the same time, circulation of gases within the bubble is intensified

together with the ionization of the arc gap. The recovery of the arcing process is also retarded due to an increasing separation between the rapidly opening contacts of the breaker.

The BMB-10 circuit breaker is furnished with an operating mechanism that functions to control its contact system.

The operating mechanism is essentially a crank gear with the shaft arranged on the top. Figure 144*a, b* illustrates the operating mechanism and the breaker contacts in the on-position. In order to close the circuit breaker, the shaft must be

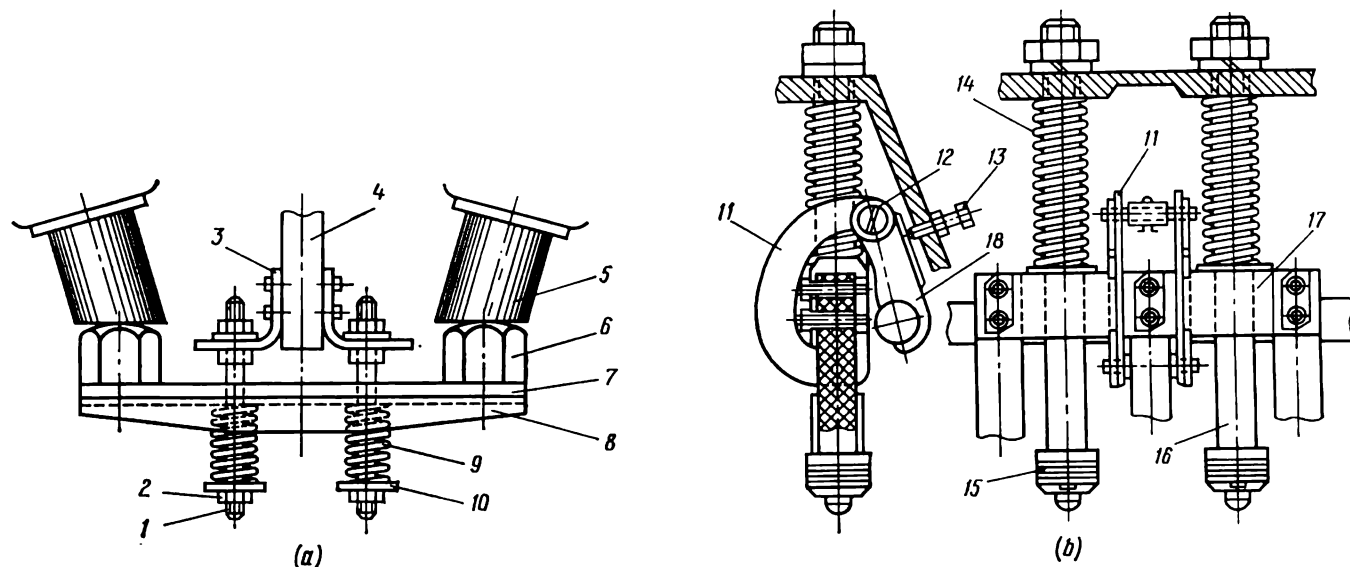


Fig. 144. General arrangement of BMB-10 circuit breaker contact system and operating mechanism

a—contacts; *b*—operating mechanism; 1—stud; 2—nut; 3—angle plate; 4—rod; 5—stationary contact; 6—detachable movable contact; 7—copper bus; 8—contact yoke; 9—spring; 10—cap; 11—shackle; 12—pin; 13—stop adjusting bolt; 14—disconnecting spring; 15—plate buffer; 16—guide rod; 17—yoke; 18—lever

turned clockwise through 90 to 130 deg. In the action, the operating mechanism raises the yokes carrying movable contacts till they come in close contact with the stationary members. In order to keep the circuit breaker in the on-position, the operating mechanism must be locked. To this end, the links of the mechanism must be in a position close to the so-called dead position which is adjusted with the stop bolt 13. In the on-position of the circuit breaker, its disconnecting springs 14 fitted on guide rods 16 compress. When the breaker opens its contacts, the shaft turns counter-clockwise under the effect of the disconnecting springs until the yokes 17 are stopped by the plate-type buffers 15 that function to limit the lower position of the operating mechanisms corresponding to the off-position of the circuit breaker.

Insulators 3 (Fig. 143) are ribbed porcelain bushings through which are passed round copper current leads 4. The top ends of the current leads are threaded and carry nuts for the connection with the switchgear buses. The bottom ends of the current leads immersed in the tank carry stationary contacts.

The bushings are installed on the tank cover in an inclined position so that the current-carrying parts of the breaker are spaced apart as much as possible. Besides, the inclined position of bushings facilitates the connection of switchgear buses to the breaker leads.

The contact system of the breaker consists of contact yokes and a set of movable and stationary contact members. The contact yoke 8 (Fig. 144a) carrying movable contacts is free to move along the studs, thereby compressing the springs 9. The stationary contacts 5 are made in the form of solid copper blocks attached to the bottom ends of the current leads.

When the breaker is closed, the movable contacts travel from the bottom upwards till their tips are stopped by the stationary contacts. The rod linked with the breaker mechanism, however, keeps moving through a certain distance upwards. In the process, the springs compress so that the desired contact pressure is maintained while the circuit breaker is in the on-position.

The type BMB-10 dead-tank oil circuit breakers are fire- and explosion-hazard devices since they contain a rather large amount of oil and do not have arc-control devices; that is why they are installed in special explosion chambers. These circuit breakers are used where frequent on- and off-operations are required by the operating conditions or technological processes.

A type BMB-10 circuit breaker delivered to the installation site is thoroughly examined; porcelain bushings 3 (Fig. 143), threads of current leads 4, oil-level indicator 5, safety rings 11, and other parts must be checked for condition.

The circuit breaker is mounted on supporting structures made in the form of angle steel welded brackets 1 (Fig. 145) measuring $60 \times 60 \times 6$ mm with supporting plates 2 made of 60×10 mm steel strips welded to them. The supporting brackets are attached to the building components in advance. The centre line of the breaker shaft must be 70 mm above the upper surface of the supporting plate, and the distance from this surface to the floor of the chamber must be at least 1,050 mm. Since off-operations of the circuit breaker are accompanied by heavy shocks and vibrations of the entire structure, the circuit breaker is attached to its supports with bolts, washers, and lock-nuts.

One of the advantages of this type of circuit breaker is a comparatively easy access provided to its parts for inspections and adjustment of contacts.

For the inspection of the breaker interior, its tank must be disconnected from the cover. To this end, nuts 12 (Fig. 143) are turned off studs 13, whereupon safety rings 11 are removed. This done, the tank 1 is lowered by means of a special hoisting facility furnished with each circuit breaker to give access to the contact systems accommodated within the tank. The tank hoisting facility 4 (Fig. 145) consists of a shackle with links and swing bolts secured on the tank cover and in the hole 3, dia 12 mm, drilled in the supporting plate 2 of the bracket. The tank can be lowered by this facility down to the floor or suspended from bolts.

When examining the internal parts of a BMB-10 circuit breaker being installed, the following must be checked:

(a) the plywood or pressboard liner on the tank walls isolating the earthed walls of the tank from the current carrying parts; the liner must be replaced with a new one if corrugated or exfoliated;

(b) bakelite and porcelain parts for exfoliation, cracks, chips, and other defects. Defective parts must be replaced with new ones;

(c) contacting surfaces and springs for condition. The contacting surfaces must be free from oxide films, the springs shall not bear traces of rust and shall not be

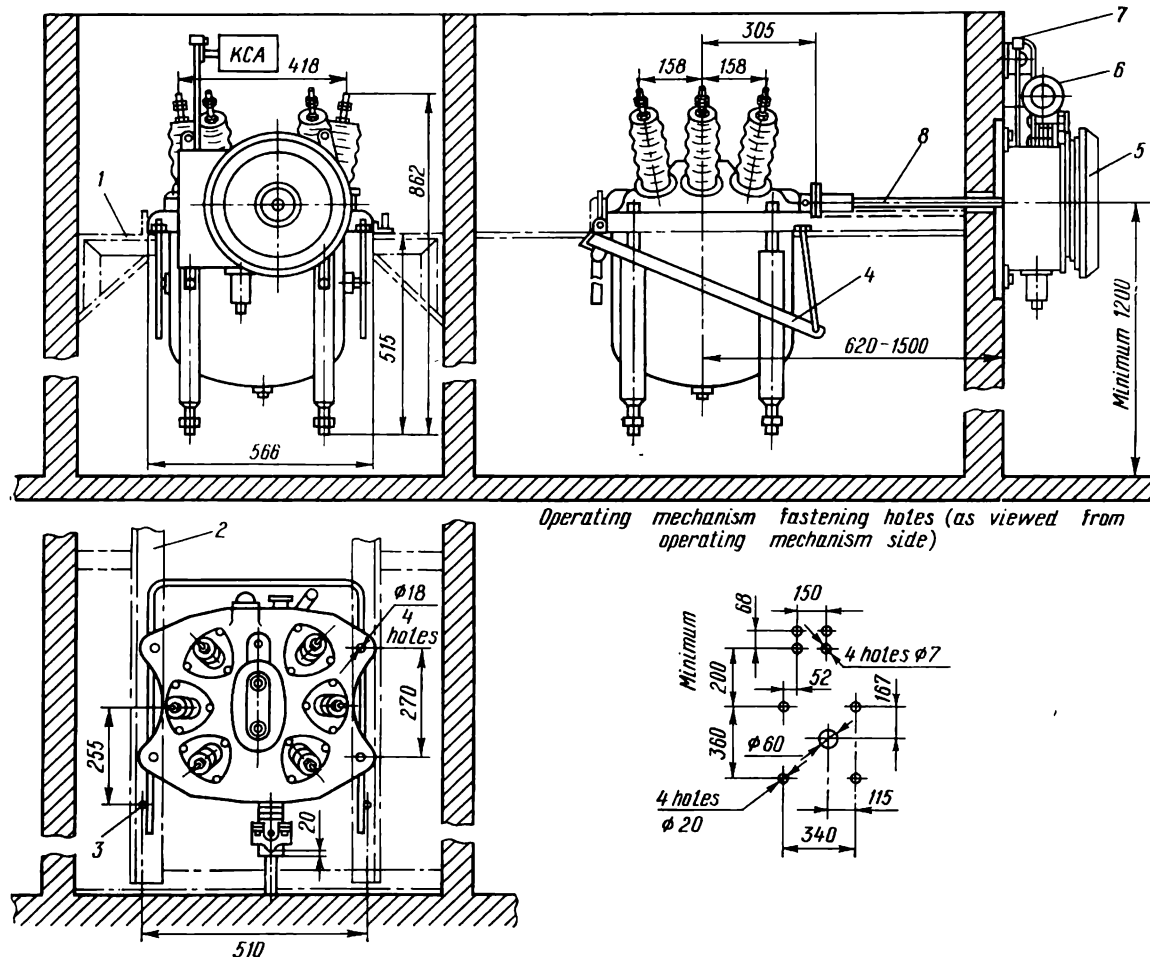


Fig. 145. Mounting the BMB-10 circuit breaker with IIIIM-10 spring-loaded operating mechanism
 1—bracket; 2—supporting strip; 3—hole for the attachment of tank hoisting facility; 4—tank hoisting facility;
 5—IIIIM-10 operating mechanism; 6—operating mechanism spring-winding motor; 7—auxiliary signalling
 contacts; 8—shaft coupling the breaker mechanism with the operating mechanism

damaged; oxide films are to be cleaned off and faulty springs replaced by new ones;

(d) vertical clearance between the movable and stationary contacts, which should be 90 ± 2 mm;

(e) phase-to-phase clearances between the centre lines of the contacts accommodated within the tank, which shall be 102 ± 2 mm;

(f) simultaneity of contact meeting; with the breaker closed, the difference in the meeting of contacts of one phase is not to exceed 2 mm, and that of different phases 1 mm; the contact pressure shall be 30 to 35 kgf;

(g) contact stroke that must be 12 ± 1 mm and shall be adjusted, if necessary, by shifting the contact yoke (Fig. 144a) over studs 1 which fasten the yoke to the angle plates 3 of the rod 4 by means of nuts 2;

(h) angle of turn of the breaker shaft that must be 98 ± 3 deg in the clockwise direction; the angle of turn of the shaft is limited by an adjusting bolt 13 (Fig. 144b) driven into the tank cover; the clearance between the end of the adjusting bolt and the lever 18 shall be 1 to 1.5 mm.

The checked and adjusted circuit breaker must be slowly closed before installation once again and then opened by hand to make sure that the contact yoke is free to move, the movable contacts are tightly fitted to the stationary ones, and the mechanism operates reliably.

Then the tank is hoisted by means of the hoisting facility and a sealing gasket made of oil-resistant rubber or pressboard is fitted between the tank and the cover. A self-made gasket may be used only in case a factory-made one is not available or excessively worn out. Then safety rings are fitted on the ends of the studs, the fastening nuts are tightened up, and only after that the breaker is earthed.

After the breaker is fully assembled and mounted on its supporting bracket, it must be filled with dry transformer oil whose electric strength must be minimum 20 kV, whereupon its shaft is coupled with the operating mechanism shaft through a hinge coupler and given ten to twelve trial on/off cycles to check the breaker and operating mechanism parts for proper interaction. If no troubles are revealed, the breaker must be tested and given trial on/off operations in accordance with the desired program to check it for reliable operation in conjunction with relay protective and automatic-control gear.

Disassembly, reassembly, installation, adjustment, and trial operation of the breaker shall be performed by electricians in compliance with pertinent operating instructions and certificates supplied by the manufacturer and with the Regulations for Electrical Installations.

9.3.2. Installation of Live-Tank Oil Circuit Breakers

The commercial high-voltage live-tank oil circuit breakers of the general-purpose type BMII-10 (suspension oil circuit breaker rated 10 kV) are available in the following type varieties: BMII-10II provided with a built-in operating mechanism; BMII-10T meant for use under tropical conditions; BMII-10K for small-sized metalclad switchgear cubicles.

The BMII circuit breakers are more advanced devices than the BMB-10 circuit breakers as far as their mechanical design and technical characteristics are concerned. They are furnished with a special arc-control device, a reliable disconnecting gear, and show much higher operational characteristics. Since their tanks contain a small amount of oil (up to 5 kg), these devices are fire- and explosion-safe, and may be installed in cubicles or chambers of any type.

The BMII-10 circuit breaker (Fig. 146a, b) consists of poles 1 mounted on a common frame 6, a spring buffer 7 and a dashpot 9, and a disconnecting gear made up of a disconnecting spring 5, a main shaft 11, an insulating rod 12, and levers.

The breaker poles are mounted on support insulators 4. The oil dashpot 9 and the spring buffer 7 built into the frame function to damp impacts in closing and opening of the circuit breaker, respectively.

Forces required for opening the breaker contacts are afforded by disconnecting springs 5. The contact system is actuated by the operating rod 12 that is linked with the main shaft 11 of the circuit breaker. Levers incorporated in the disconnecting gear convert the rotational motion of the shaft into a progressive movement of the movable contacts.

The breaker pole (Fig. 147) is a self-contained unit composed of an upper metal cylinder 8 and a lower insulating (glass reinforced epoxy) cylinder 16, which

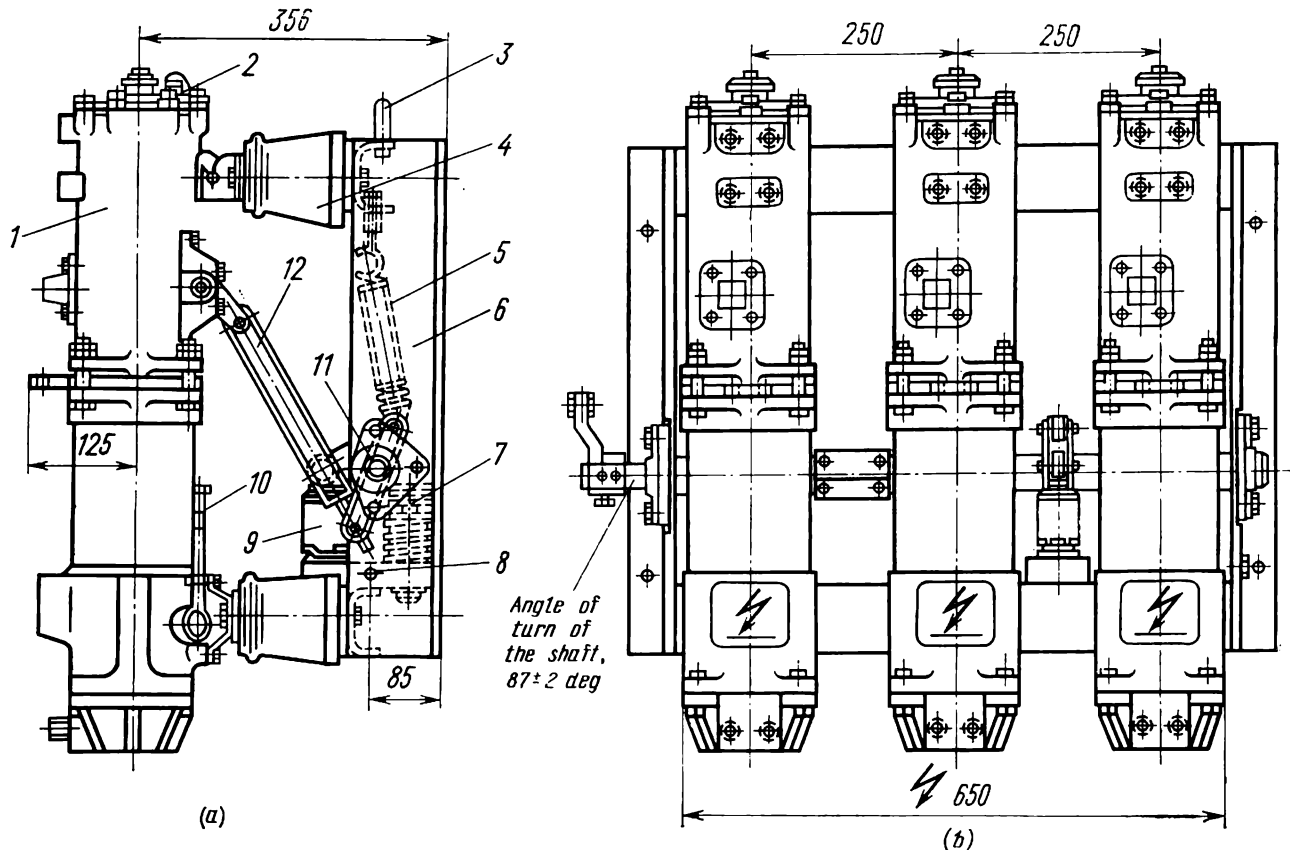


Fig. 146. Suspension oil circuit breakers BMII-10 rated 10 kV

a—side view; *b*—front view; 1—breaker pole; 2—oil drain plug; 3—lifting shackle; 4—insulator; 5—disconnecting spring; 6—frame; 7—spring buffer; 8—earthing bolt; 9—oil dashpot; 10—oil-level indicator; 11—main shaft; 12—insulating operating rod

accommodate a stationary cluster socket contact 3, an arc control chamber 5, a rolling-contact current collector 7, an oil separator 9, a movable contact 17, and a pole mechanism (a lever 13, guide rods 14, a lever shaft, etc.). The cylinders are filled with dry transformer oil. The cluster socket contact 3 consists of six laminations shaped to form, when stacked together, a cylindrical hole to receive the movable contact current lead when the breaker closes. The laminations are plated with sintered metal to increase the service life of the contact. The laminations are fitted with springs that afford the desired pressure when they are closed with the movable contact.

The movable contact is a round-section copper rod with a detachable copper tip screwed on its lower end.

A gas-blast arc-control chamber is mounted above the stationary contact. It is assembled of insulating plates (paper base laminate, fibre, pressboard) that form slits, holes, and ducts wherein the arc is extinguished.

The arc suppression process is as follows. As the circuit breaker opens, an arc jumps the gap between the stationary cluster socket contact and the movable contact. The oil decomposes under the effect of high temperature of the arc and the resulting gases create a high pressure within the chamber. As the contact rod moves further upwards, the arc elongates and the oil starts decomposing more intensively; the pressure within the chamber becomes still higher. Gases actuated by this high pressure are expelled in the direction of the moving rod, catch the arc in the slits and holes, blow off and suppress it. Gases liberated in the course of arc quenching are discharged into the atmosphere through a zigzag duct in the upper cover 10 of the pole. To prevent oil from being expelled at the moment of arc suppression, an oil separator 9 is mounted on the top part of the metal cylinder 8.

A packing case containing an oil circuit breaker shall be opened on site of installation with particular care so as not to injure the breaker parts and paint coat. The breaker cleaned of packing materials shall be thoroughly examined, all its parts checked for condition and standard equipment for missing items.

Circuit breakers are mounted after the installation of insulators and switchgear busbars;

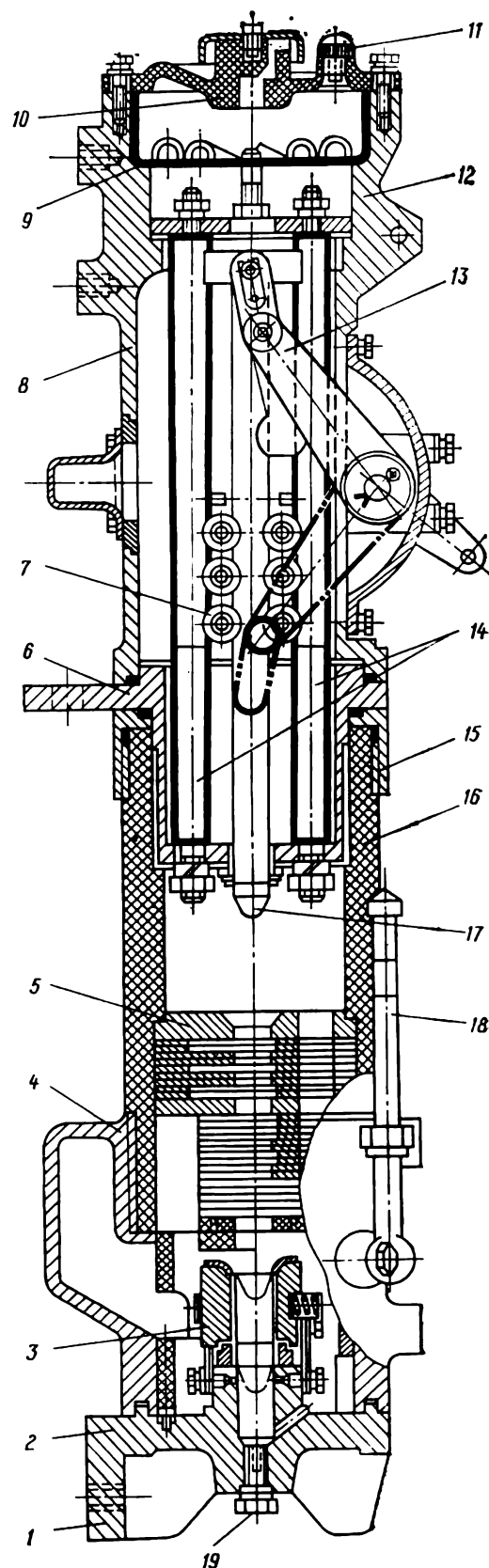


Fig. 147. Arrangement of poles in BMII-10 circuit breaker rated 600 and 1,000 A

1, 6—lower and middle terminals; 2, 10—bottom and top covers; 3, 17—stationary and movable contacts; 4, 15—bottom and top flanges; 5—arc-control chamber; 7—roller-type current collector; 8, 16—upper and lower cylinders; 9—oil separator; 11, 19—oil filler and drain plugs; 12—pole mechanism housing; 13—pole mechanism lever; 14—guide rods; 18—oil-level indicator.

the buses to be connected directly to the breaker leads are installed after the breaker has been mounted and adjusted.

The BMII-10 circuit breakers are wall-mounted through four holes, dia 18.5 mm, provided in their frames. The frame is bolted to the wall or secured with studs of an appropriate diameter and length depending on the wall thickness.

For mounting a type BMII-10 circuit breaker, do the following:

Mark out on the wall the fixation points, drill holes at these points and insert bolts into them. The length of the protruding threaded end of the bolt must be sufficient to fasten the frame with the aid of shims, a washer, a nut, and a lock-nut. Hang the frame on the bolts, secure it for the time being, and level it off in the vertical plane by means of a plumb bob. A minimum deviation from the vertical is 5 mm. Uniformly turn in the nuts to fix the frame in position, taking care to avoid misalignment. While doing so, provide a tight fit between the frame and the wall by means of metal shims. Check the short arm of the double-arm middle lever on the spring buffer head for correct position, the working travel of the spring buffer, and the clearance between the buffer washer and case. With the breaker closed, the lever end must rest on the buffer head and compress its spring, thereby storing the required disconnecting energy and affording the desired rate of separation of the contacts. The working travel of the spring buffer is $22 + 1$ mm. The clearance between the washer and the case of the spring buffer shall be within the range of 0.5 to 1.5 mm; a clearance smaller than 0.5 mm will limit the shaft movement in closing, which will give no opportunity for the trip-free mechanism latch to assume its place so as to hold the breaker in the on-position; at a clearance larger than 1.5 mm the inertial overrun of the contact rods at the moment the breaker closes will be so great that the contact rod may hit the bottom of the cluster socket contact and break the both.

Check the oil dashpot for normal functioning and for the amount of oil in it. The buffer rod and piston must travel smoothly, without sticking. The buffer must be filled with oil to a normal level of 10 mm above the top edge of the piston and sealed with an oil-resistant rubber gasket 6 to 8 mm thick. If the dashpot functions abnormally, dismantle it, flush out with paraffin oil and fill with clean transformer oil in an amount of 0.6 litres. Make the breaker ready for contact simultaneity check. To this end, remove the top covers and the oil separators from the poles, drive metal check rods, dia 6 mm, 400 mm long, size M6 thread, into threaded holes provided on the butt ends of the movable contacts, and set up a circuit for checking the moment when each pair of the breaker contacts meets.

Couple the breaker with the operating mechanism and operate the latter manually, at the same time adjusting the interaction between the mechanism elements and the contact system of the circuit breaker (Fig. 148).

Place the breaker shaft in the off-position (Fig. 148a), check it for correct position by means of a template (Fig. 148b), fix it with the aid of the oil dashpot, then fit the disconnecting springs, retaining their tension as preset by the manufacturer. Fully open and close the contacts of the breaker poles and apply marks on the check rods at these positions of the contacts; at the same time make an undertravel mark at a distance of 5 mm to the extreme off-position. Connect the wire leads of the circuit (Fig. 148c) to the check rods and close the circuit breaker till the

movable contacts meet the stationary members. See that the difference in closure of the contacts, as indicated by burning of a pilot lamp connected into the circuit and by the marks on the check rods, shall not exceed 5 mm; make the required adjustments by varying the length of the insulating rod.

Fully close the circuit breaker (this is recognized by the engagement of the holding latch with the operating mechanism) and make certain that the following

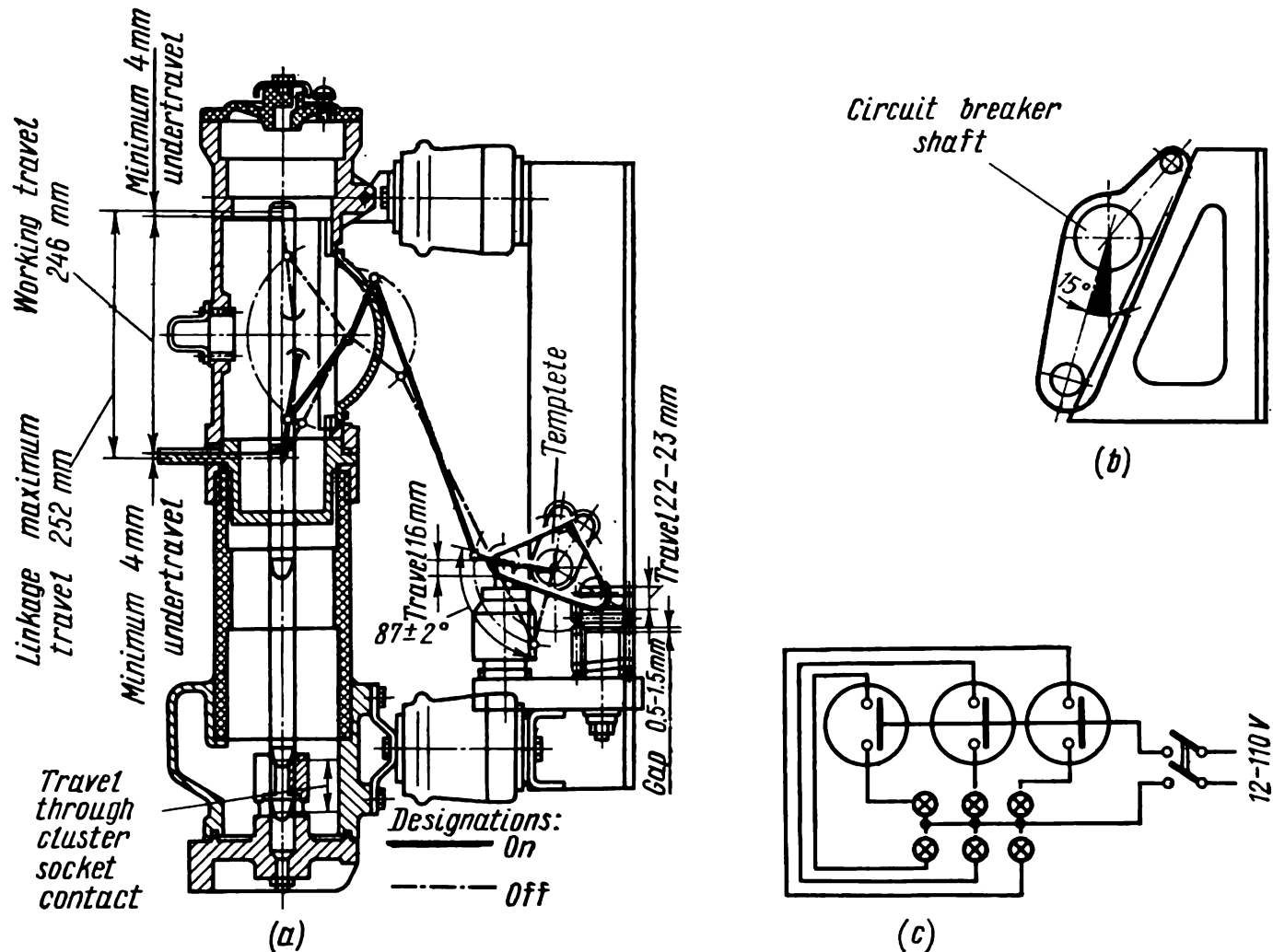


Fig. 148. Adjustment diagram for the BMII-10 circuit breaker mechanism and contact system
 a—mechanical diagram; b—determination of circuit-breaker off-position; c—electric circuit arrangement for checking the contacts for simultaneity of opening and closing

requirements are met: the full travel of the movable contacts is within the range of 240 to 245 mm; the travel within the contacts is 60 ± 4 mm and 56 ± 4 mm for breakers rated 600 and 1,000 A and for those rated 1,500 A, respectively; the angle of turn of the breaker shaft is 87 ± 2 deg; the remaining travel to the extreme position is at least 4 mm. The above-specified values can be attained by changing the position of the spring buffer during adjustment. After the breaker is fully adjusted, drive out the check rods, mount in place the oil separators and secure the upper pole covers on the cylinders. Check the breaker for proper functioning by

giving it at least five on/off operations with the operating mechanism first actuated manually and then remotely.

The fully assembled and adjusted circuit breakers of the БМБ and БМП types shall be subjected to the following tests: (a) make a brief analysis of oil contained in dead-tank circuit breakers БМБ; (b) check the electric strength of oil in dead-tank and live-tank oil circuit breakers and make sure that it is not lower than 25 kV for breakers rated 10 kV;

(c) using a 2.5-kV megger, measure the insulation resistance of the breaker moving parts made of organic materials; at a rated voltage of 6 and 10 kV the insulation resistance of these parts shall not be lower than 1,000 M Ω ;

(d) subject the circuit breaker with normal insulation rated 10 kV to a high-voltage test by applying commercial-frequency voltage of 38 kV for 1 min;

(e) determine the contact resistance which should not be over 120 $\mu\Omega$ for the БМБ-10 breakers rated 600 A, 55 $\mu\Omega$ for the БМП-10 breakers rated 600 A, 40 $\mu\Omega$ for those rated 1,000 A, and 30 $\mu\Omega$ for the БМП-10 breakers rated 1,500 A.

Enter the results of tests in a test report that is to be submitted to the user together with other pertinent documents.

9.4. Installation of Circuit Breaker Operating Mechanisms

The operating mechanism is a special device that functions to close a high-voltage circuit breaker, hold it in the closed position, and open it. The operating mechanisms make it possible to control the circuit breakers automatically and remotely. They may incorporate various relays to set up protective circuits affording the desired protection of electrical installations under abnormal conditions.

According to the actuating energy they use, the operating mechanisms are classified as manual, counterweight-operated, spring-loaded, spring-and-counterweight, and electromagnetic mechanisms. Manual and electromagnetic operating mechanisms are direct-action devices as the energy required for closing the circuit breaker is imparted directly during this operation. Counterweight-operated, spring-loaded, and spring-and-counterweight mechanisms are of an indirect type as the energy required for closing the circuit breaker is stored by a lifted counterweight or a wound spring.

The operating mechanisms used to control circuit breakers are equipped with the following elements:

(a) closing mechanism for initiating the motion of the movable contacts when closing the circuit breaker;

(b) holding linkage for keeping the circuit breaker locked in the closed position;

(c) trip-free mechanism for opening the circuit breaker by releasing the latch of the holding linkage to set free its moving elements.

Most widely used in substations and in various industrial electrical installations are the type ПРБА, ППМ, УПГП, ПС and ПЭ operating mechanisms.

The automatic-control blinker manual operating mechanism ПРБА (Fig. 149) consists of a housing 3 accommodating a linkage coupled through a lever 1. The bottom portion of the operating mechanism houses a relay box accommodating overcurrent and undervoltage relays that make it possible to obtain various pro-

protective circuit arrangements. The breaker is controlled manually by means of the lever 1. The operating mechanism is furnished with a special blinker 5 which changes its position from vertical to horizontal 5' in the event of automatic opening

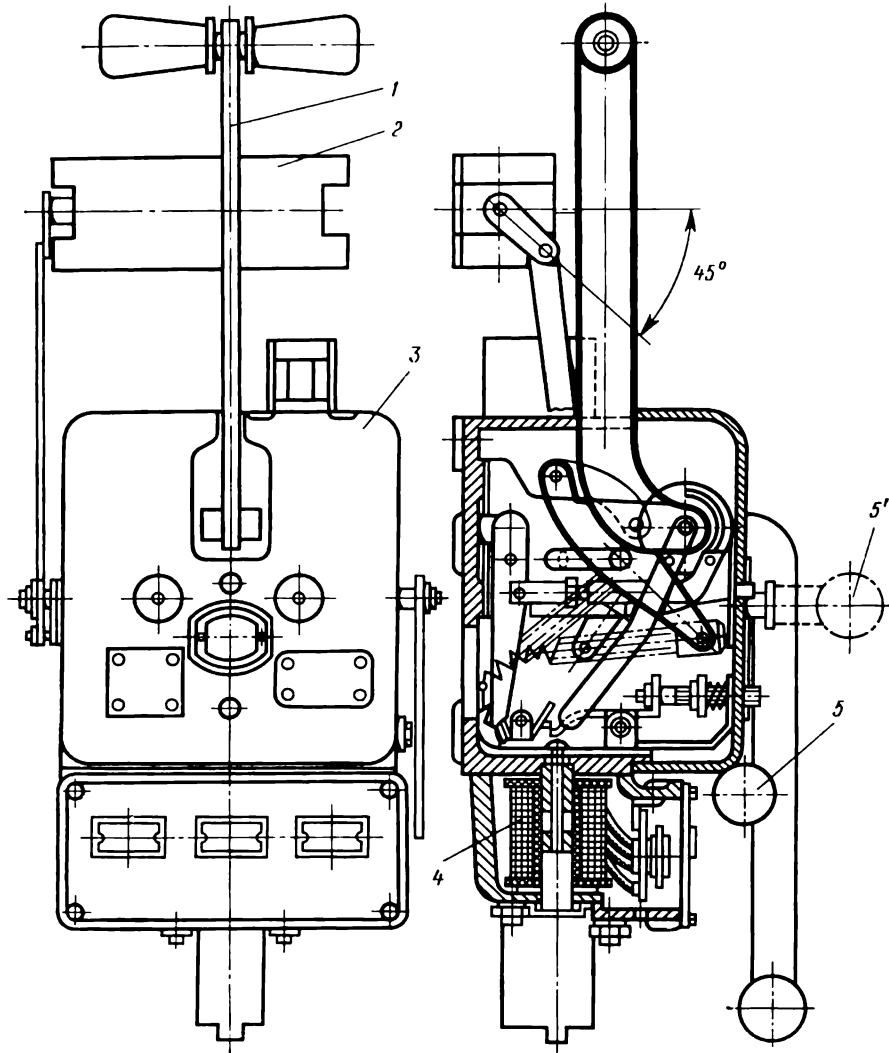


Fig. 149. Automatic-control blinker manual operating mechanism ПРБА

1—making lever; 2—auxiliary signalling contacts box; 3—housing; 4—relay box accommodating direct-action relays; 5—signal blinker

of the breaker, thereby informing the attending personnel on the fact. Mounted above the operating mechanism is a box 2 accommodating auxiliary signalling contacts to afford light and audio signalling. The shaft of the signalling auxiliary contacts is linked with the operating mechanism via levers and operating rods.

The linkage (Fig. 150) consists of a control lever 1 and a number of intermediate links through which the lever actuates the operating rod 15 of the circuit breaker. The lever 1 and the disk 12 coupled to the former are free to turn about the axle O_1 . The motion of the control lever 1 is imparted to the operating rod 5 via a shackle 11 and the main lever 10. The lever 10 is provided with a pin 8 that functions as its

axis of rotation. The pin can move in a horizontal slit 9 made in the bracket mounting the entire linkage. A latch 7 is loosely fitted on the pin 8 and hinged to the shackle 11. The shackle and the lever 6 are fitted on a fixed axle O_2 .

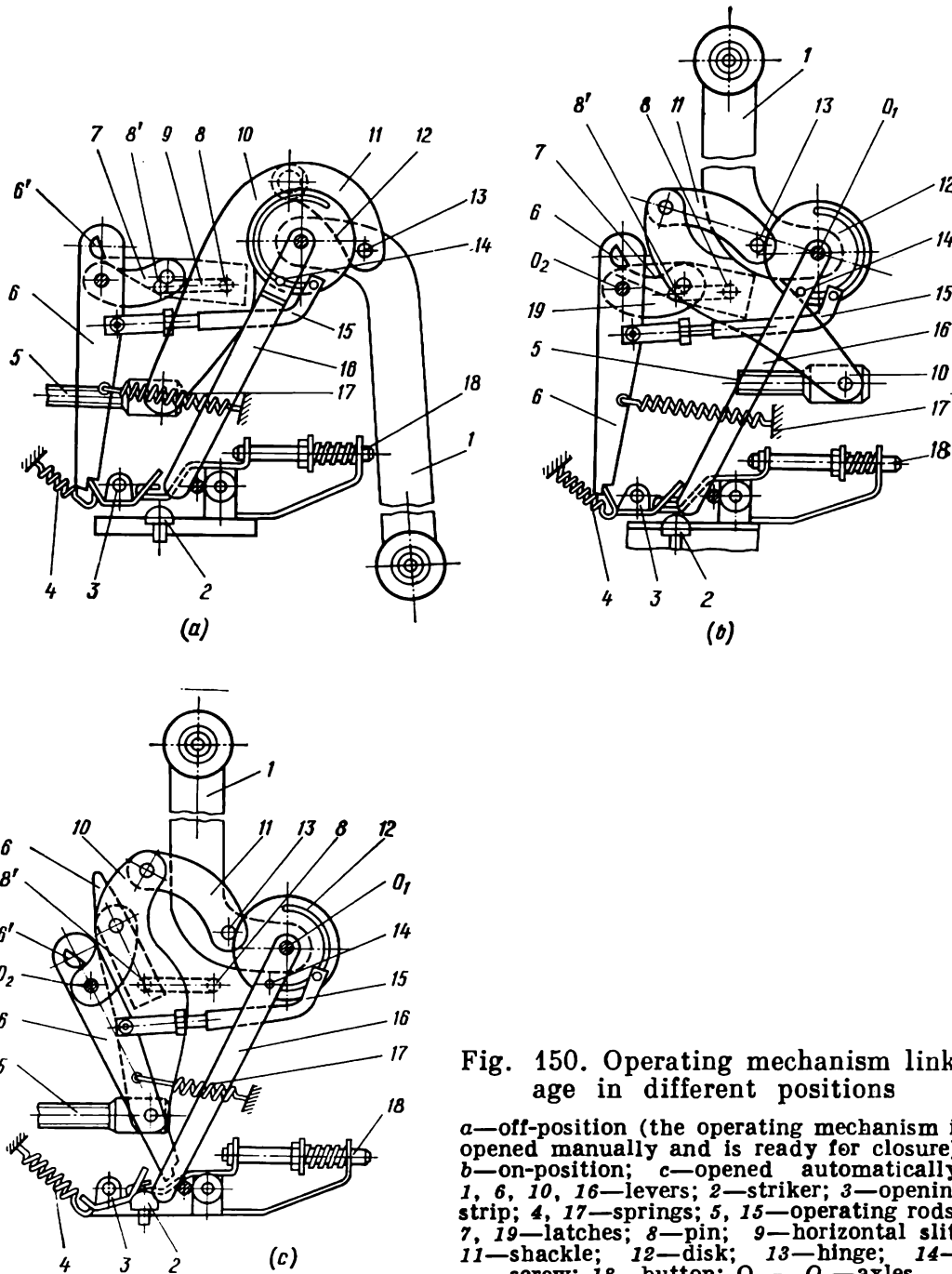


Fig. 150. Operating mechanism linkage in different positions

a—off-position (the operating mechanism is opened manually and is ready for closure); *b*—on-position; *c*—opened automatically; 1, 6, 10, 16—levers; 2—striker; 3—opening strip; 4, 17—springs; 5, 15—operating rods; 7, 19—latches; 8—pin; 9—horizontal slit; 11—shackle; 12—disk; 13—hinge; 14—screw; 18—button; O_1 — O_2 —axes

In order to close the circuit breaker, turn the control lever 1 (Fig. 150*a, b*) from bottom upwards through 180 deg. In the action, the shackle 11 hinged to the lever sets in motion the main lever 10 about a temporarily fixed centre. The operating rod 5 linked with the main lever 10 moves to the right and closes the circuit breaker.

In the action, the springs get compressed and tend to open the breaker, but the latter is held closed because the hinge 13 that links the shackle 11 with the lever 1 passes the dead point and locks the operating mechanism. Displacement of the centre is also excluded because the pin 8 rests on the semi-axle of the lever 6, and the bottom end of the latter thrusts against the pin of the opening strip 3 coupled with the spring 4.

To open the circuit breaker manually, turn down the lever. In the process, the disk 12 turns simultaneously and carries away the frictionally coupled lever 16 that is loosely fitted on the axle O_1 . The friction coupling spring can be adjusted by means of a screw 14 fitted on the lever 16. The lower end of the lever 16 thrusts against the pin of the opening strip 3 and turns the latter. In the action, the lever 6 is released and the circuit breaker opens.

Automatic opening of the circuit breaker takes place as follows. The striker 2 rises, thrusts against the pin of the opening strip 3 and turns the latter counter-clockwise. The lever 6 is set free and displaced to the left by the spring 17, thereby releasing the latch 7. In the process, the pin 8 moves to the left assuming position 8', the lever 10 turns clockwise and automatically opens the circuit breaker. The control lever 1 (Fig. 150c) remains motionless just as in the on-position. The automatic-opening blinker assumes the horizontal position, thus informing the attending personnel that the breaker has opened automatically.

For the reclosure of the circuit breaker, turn the control lever from top downwards. This will turn the disk 12 and the latter will carry the lever 6 to the left by means of the operating rod 15. The end of the latch 7 engages the half-axle 6', and the lower end of the lever 6 engages the pin of the strip 3, whereupon the breaker becomes ready for closing. Turning the control lever makes the signalling blinker go down and assume its normal position.

In the event of circuit breaker opening under the action of an undervoltage relay incorporated in the operating mechanism, the lever 1 moves down, pushes the button 18 and resets the relay.

The ПРБА operating mechanism is employed where the manual closure and only automatic opening of circuit breakers are required. A remote control of circuit breakers, their automatic reclosure, automatic switching-on of stand-by equipment, and various types of relay protection can be afforded by operating mechanisms ППМ-10, УПГП, ПС-10, and ПЭ-11.

The spring-loaded motor-driven operating mechanism ППМ-10 and its general arrangement are shown on Fig. 151a, b. It is employed for manual and remote closure and opening of circuit breakers, for their automatic reclosure, and for the connection of a stand-by line or power transformer.

Mounted on the top of the operating mechanism is an automatic motor-driven reduction unit that consists of a type MYH 350-W electric motor 5 and a worm gear unit 6 coupled to the motor. The reduction unit automatically winds up the helical spring 7 each time after the breaker has opened. The spring can also be wound manually by means of a knob provided on the reduction unit. The spring mass is 6.7 kg. It is enclosed in a heavy shroud with a cover that functions as a handwheel for the operating mechanism.

The reduction unit motor is started and stopped automatically by means of auxiliary contacts 3 linked with the operating mechanism via an operating rod 4. The breaker is closed by the operating mechanism under the action of the wound spring. For a remote closure, the coil circuit of the making electromagnet 38 is closed by the contacts of a control switch mounted on the substation switchboard or control console. The core actuated by the current pulse applied is drawn into the coil and forces the holding linkage to release the wound spring which closes the circuit breaker due to a previously stored energy.

If the breaker is to be closed manually, push upwards the lower end of the making electromagnet core 37 that protrudes from the operating mechanism housing to the

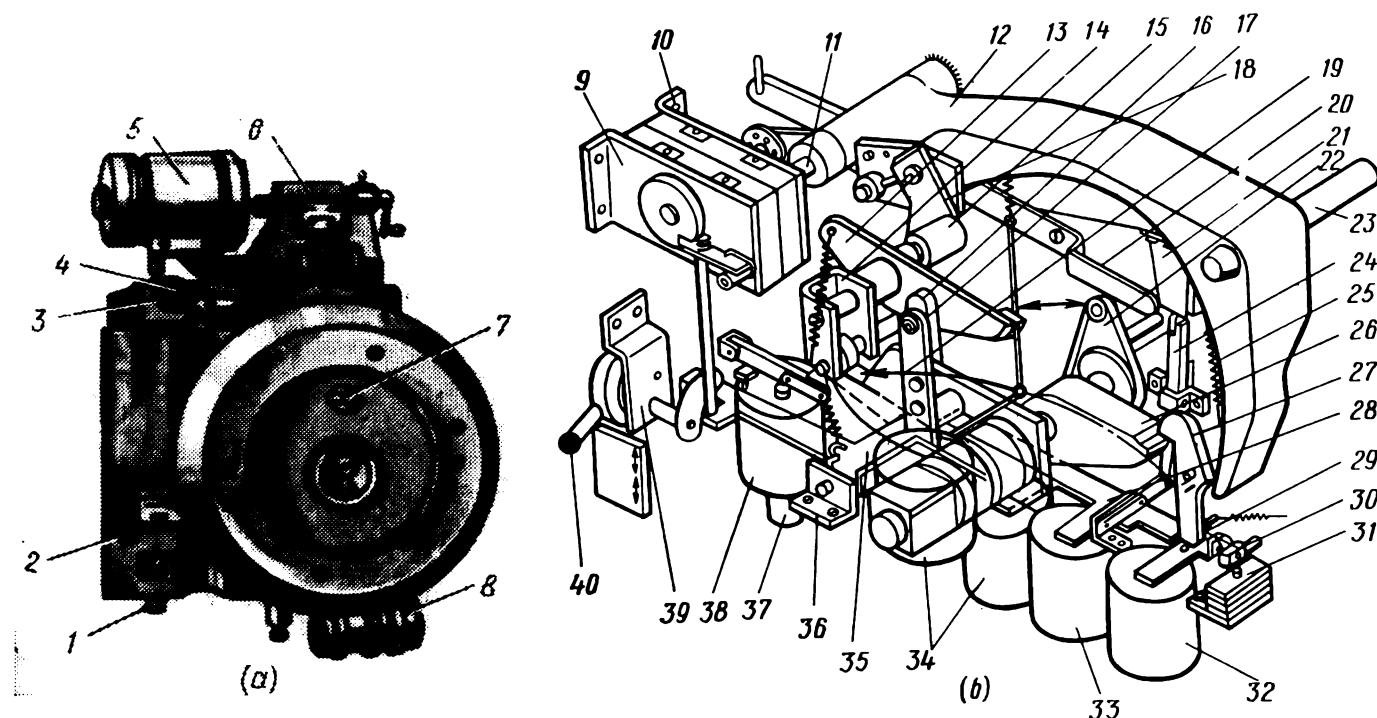


Fig. 151. Spring-loaded motor-driven operating mechanism ППМ-10

a—general view; *b*—general arrangement; 1—button; 2, 40—handles; 3, 9—auxiliary contacts; 4—operating rod; 5—electric motor; 6—worm gear unit; 7—spring; 8, 32, 33, 34—relays; 10—holes; 11—pin; 12, 13, 17, 19, 20, 22, 26—levers; 14, 24—holding linkage; 15—shaft; 16, 27—latches; 18, 28, 35—strips; 21—angle plate; 23—shaft; 25—spring; 29—buttons; 30, 36, 39—bearings; 31—buffer; 37—armature; 38—electromagnet

left at the bottom and forms a push-button 1 labelled ON. The operating mechanism is equipped with a breaking electromagnet and a relay 8 for the remote and automatic opening of the circuit breaker.

Manual control is carried out by means of a handle labelled OFF and located on the face side of the operating mechanism.

Turning the handle upwards well home opens the breaker, and turning it to the first fixed position releases the automatic reclosure element.

Basic elements of the operating mechanism are discussed below.

The trip-free mechanism consists of a cast crescent-shaped lever 12 carrying an angle plate 21 that holds the lever 12 in the triggered (up) position, and strip 18

for resetting the lever. The strip can turn clockwise only. The lever 12 is free to turn about the pin 11. The spring 25 functions to accelerate the lever 12 when it drops.

The relay-actuated disconnecting gear consists of a strip 28 rotating in bearings 30, four plates, a holding linkage mechanism 24 with a roller, and a manual disconnecting strip 37 rotating in a bearing 36.

The operating mechanism shaft gear consists of a shaft 23, that is mounted in bearings fitted in the operating mechanism housing, a lever 26 fixed on the shaft, a holding latch 27, and a lever 22 for a mechanical start of the automatic reclosure element.

The closing mechanism consists of a lever 19 that is free to turn on the operating mechanism shaft and a latch 16 used to engage the lever 26 in closing. The protruding tetrahedral bush of the lever 19 carries a handwheel incorporating a helical spring and a reset gear. The lever 19 is furnished with a roller which rests on the strip 18 during the on-operation, thereby triggering the crescent-shaped lever 12. The motion of the lever 19 is restricted by a rubber buffer 31.

The automatic reclosure starting mechanism mounted on the shaft 15 consists of a helical spring holding linkage 14 and an automatic reclosure starting element (lever 13).

The manual control elements of the operating mechanism and automatic reclosure interlocking device include an armature (core) 37 located at the operating mechanism bottom, to the left, and a handle 40 mounted in a bearing 39 on the face side of the operating mechanism.

The relay unit comprises four relays 8, 32, 33 and 34. The making electromagnet 38 actuates the linkage 14 that holds the lever 19 of the operating mechanism closing spring. The lever 20 serves to control the auxiliary contacts mounted on the operating mechanism housing and emergency auxiliary contacts of the BKA type that function to indicate the breaker opening under abnormal conditions. The angle plate of the box accommodating the emergency auxiliary contacts 9 is provided with holes 10 through which the box is bolted to the left-hand side wall within the operating mechanism.

To close the circuit breaker, release the lever 19 that is held in position by the roller of the linkage 14. To this end, push the armature (button) of the making electromagnet or apply a current pulse to the electromagnet coil 38. The released lever 19 starts turning clockwise under the effect of the spring and in the action catches with its latch 16 the lever 17. The latter is shown in a position in which the circuit breaker is closed. In the open position of the breaker, this lever is turned counterclockwise through 100 or 140 deg (depending on the type of the circuit breaker). The lever 17 is brought by the latch 16 to a position in which the other fixed latch 27 locks it. Since the lever 26 is fixed on the shaft 23 of the operating mechanism, the shaft turns together with the lever. The motion of the lever 19 is restricted by means of a buffer 31. As the lever 19 starts moving clockwise, it triggers the crescent-shaped lever 12 by means of the roller of the lever 17 that abuts upon the strip 18. The triggered lever 12 is latched with the roller of the holding mechanism 24 and is prepared in this way for tripping (opening).

The breaker is opened through the relay-actuated disconnecting gear operated either manually by turning the handle 40 of the strip 35 or automatically by means

of the breaking electromagnet, or as a result of the relay protective gear operation. At manual or remote opening, as soon as the handle 40 is turned, the right-hand end of the lever 13 moves upwards and disengages the roller of the lever 22, thereby interlocking the automatic reclosure element. A further displacement of the handle 40 up to the OFF position turns the strip 28 which carries the post of the holding linkage 24 away from the dead point, thereby releasing the crescent-shaped lever 12. The latter hits the lower end of the latch 27 and releases the lever 26; now the operating mechanism shaft actuated by the breaker springs easily turns. The remote disconnection also takes place upon the arrival of a current pulse at the coil of one of the electromagnets.

When the circuit breaker opens as a result of operation of the protective gear (the spring being wound in advance), an instantaneous reclosure takes place, that is, the lever 22 carrying a roller turns in opening together with the operating mechanism shaft counter-clockwise and strikes with its roller the lever 13 actuating the linkage 14. The lever 19 held in position by the roller of the linkage 14 is set free and turns clockwise under the action of the helical spring. In the action, the lever 19 engages through the latch 16 the lever 26 and closes the circuit breaker. The lever 12 is fully triggered as soon as the lever 19 starts turning clockwise through an angle of about 40 deg. With a further rotation of the lever 19 the lever 12 can easily drop upon the operation of the protective gear and disengage the lever 28, making it impossible for the circuit breaker to close.

Electrical (relay) reclosure can be afforded by standard automatic reclosure circuits in the same way as for electromagnetic operating mechanisms (such as type ПС-10), but in this case the mechanical automatic reclosure linkage must be disabled in the operating mechanism. The closing current pulse coming from the relay automatic reclosure circuit must be applied to the remote making coil.

In order to disable the mechanical automatic reclosure linkage for the time being, turn the handle 40 to the fixed W/O AUTO RECLOSURE position. This will turn the lever 13 so that any opening of the circuit breaker will throw the roller of the lever 22 under the roller 13, thus by-passing the automatic reclosure linkage.

The universal spring-and-counterweight operating mechanism of the УПГП type (Fig. 152a, b) is distinguished from the ППМ-10 mechanism in that it incorporates also a counterweight in addition to springs. The springs and the counterweight are mechanically linked so that the operating mechanism is actuated both by the tension of the springs and by the energy of the falling counterweight. The УПГП operating mechanism is reliable in operation and is noted for many advantages.

The УПГП operating mechanism is suitable for an automatic and remote control over circuit breakers of all types used for electrical installations of the 6, 10, and 35 kV classes. The springs 3 are wound automatically by means of an electric motor 1 and a reduction unit 2, or manually by means of a removable collapsible handle.

The general arrangement of the УПГП operating mechanism is illustrated by Fig. 152b. This operating mechanism performs the following functions:

(a) manual opening and closure of the associated circuit breaker by pushing the respective lower (6) and upper (7) button on the face side of the operating mechanism;

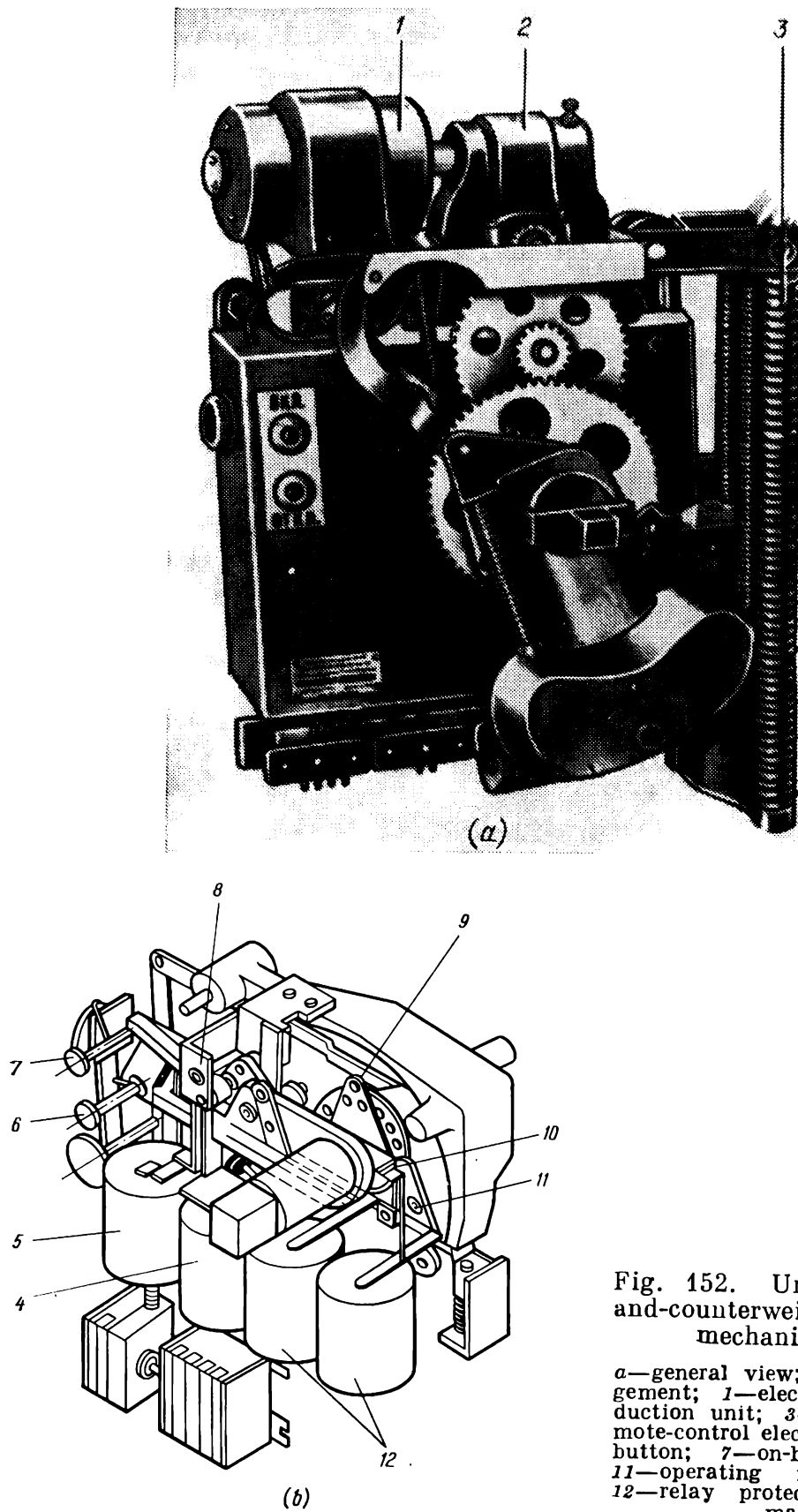


Fig. 152. Universal spring-and-counterweight operating mechanism VПГП

a—general view; *b*—general arrangement; 1—electric motor; 2—reduction unit; 3—spring; 4, 5—remote-control electromagnets; 6—off-button; 7—on-button; 8, 9, 10, 11—operating mechanism levers; 12—relay protective gear electromagnets

(b) remote opening and closure of the circuit breaker by means of electromagnets 4 and 5 incorporated in the operating mechanism;

(c) automatic opening of the circuit breaker both instantaneously and with time delay by applying a pulse from a relay protective gear (without automatic reclosure or with mechanical automatic reclosure);

(d) automatic opening of the circuit breaker by means of electromagnets as soon as a pulse is applied from the relay protective gear, followed by automatic reclosure by means of typical relay-actuated automatic reclosure circuits (the mechanical automatic reclosure linkage is disabled);

(e) automatic connection of stand-by equipment either mechanically by means of lever 8, 9, 10, and 11 or electrically by means of making and breaking electromagnets.

Along with spring-loaded and counterweight-actuated operating mechanisms, there are also electromagnetic operating mechanisms used for the remote control of high-voltage circuit-opening devices. Electromagnetic operating mechanisms are supplied with commercial alternating current or direct current from a storage battery of appropriate ampere-hour capacity and voltage.

The moving element of these operating mechanisms is a solenoid with a core. The latter is attracted due to the current flowing in the solenoid and affords the required pull for closing the circuit breaker.

The type ПС-10 and ПЭ-11 electromagnetic operating mechanisms

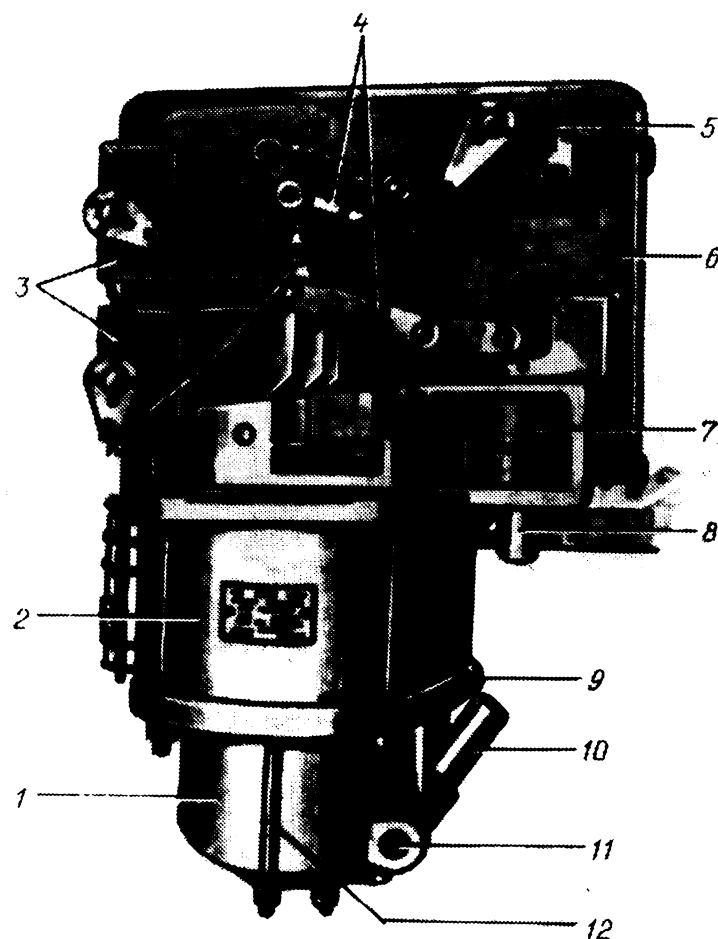


Fig. 153. Electromagnetic operating mechanism ПС-10 (with case removed)

1—buffer flange; 2—steel cylinder; 3, 5—auxiliary signaling contacts; 4—levers of the operating mechanism linkage; 6—bracket (plate); 7—breaking solenoid; 8—projecting core of breaking solenoid; 9—earthing bolt; 10—operating-mechanism manual-control lever; 11—pin (shaft); 12—clamping stud

are generally used by industrial electrical installations.

The ПС-10 operating mechanism (Fig. 153) is a suspension structure. It consists of a linkage, a magnetic system with its moving part, and a buffer flange.

The linkage is arranged in the upper part of the operating mechanism on a cast-iron bracket 6 which is secured to the wall with four bolts. Mounted to the right of the linkage on the cast bracket is a breaking solenoid 7 whose projecting core 8

is employed for manual control. Signalling auxiliary contacts 3, 5 and their terminals are located to the left and to the right of the linkage. The entire system, together with the contacts and terminals, is enclosed in a detachable case fitted with a viewing port for the mechanism position indicator.

The magnetic system is mounted in a steel cylinder 2 placed in the middle of the operating mechanism between the bracket 6 and the buffer flange 1. The top part of the magnetic circuit is the bottom of the cast bracket, and the bottom of the magnetic circuit is the top of the buffer flange. The cylinder 2 also functions to protect the making solenoid winding against mechanical damage. The making solenoid windings consist of one or two coils for rated voltages of 110 or 220 V, respectively.

The moving part of the magnetic system consists of a steel cylindrical core with a screwed-in rod which passes through the hole in the bottom of the bracket and actuates the roller of the linkage lever.

To prevent sticking of the core upon closure, a brass washer is attached to the bottom surface of the bracket and a back spring is fitted on the rod.

The buffer flange 1 is an iron casting braced to the operating mechanism bracket by means of four clamping bolts 12 together with the magnetic circuit cylinder. The buffer flange houses rubber gaskets that function to damp the shocks of the dropping core after the off-operation ceases. Press-fitted at the bottom of the buffer flange are bearings which mount the pin 11 of the manual-control lever 10.

The buffer flange can be turned through 90 deg., which offers some convenience for the attending personnel—provides better access to the manual-control lever during the installation of the operating mechanism.

The projecting rear end of the operating mechanism shaft carries a coupling fork for the connection to the circuit breaker. The making solenoid is connected to the power circuit that is closed and opened by a d.c. contactor.

The mechanical diagram of the ПС-10 operating mechanism is shown by Fig. 154. Applying voltage to the making solenoid winding draws in its core whose rod 4 abuts upon the roller 5 (Fig. 154a) and forces it upward. At the same time, a rotational motion is imparted to the lever 3 which turns about a temporarily fixed pin 12 and slides with its pin 6 over the internal contour of the latch 7 (Fig. 154b).

The lever 3 imparts a progressive and rotational motion to the lever 8 and the latter actuates the lever 9 fixed on the breaker shaft 10 and turns the shaft clockwise. The core rod stops moving after the holding latch 7 comes out of mesh with the pin 6, gets under this pin and in this way reliably holds the circuit breaker in the closed position (Fig. 154c).

By the end of the rod movement, the solenoid circuit opens and its core drops and assumes its original position (Fig. 154d). The supply circuit of the solenoid is opened only after the circuit breaker is reliably latched in the on-position.

The circuit breaker can be opened either manually or remotely by applying a current pulse to the breaking solenoid circuit. As the breaking solenoid 1 is energized, the striker of its core 2 hits the collapsible levers 13, 14, and 11, releases the temporarily fixed pin 12, and the breaker is forced to the off-position under the action of the springs. In the action, the pin 6 runs off the end of the holding latch and falls down (Fig. 154e, f). At the same time, the supply circuit of the breaking

solenoid opens, the levers 13 and 14 return to their original position under the action of the springs, and the position illustrated by Fig. 154a is resumed.

The *Π9-11 electromagnetic operating mechanism* (Fig. 155) is a more advanced arrangement. It incorporates links that provide for an almost dead position in the course of the breaker closure. Such an arrangement makes it possible to dispense with corresponding links in the breaker mechanisms, which affords a simple

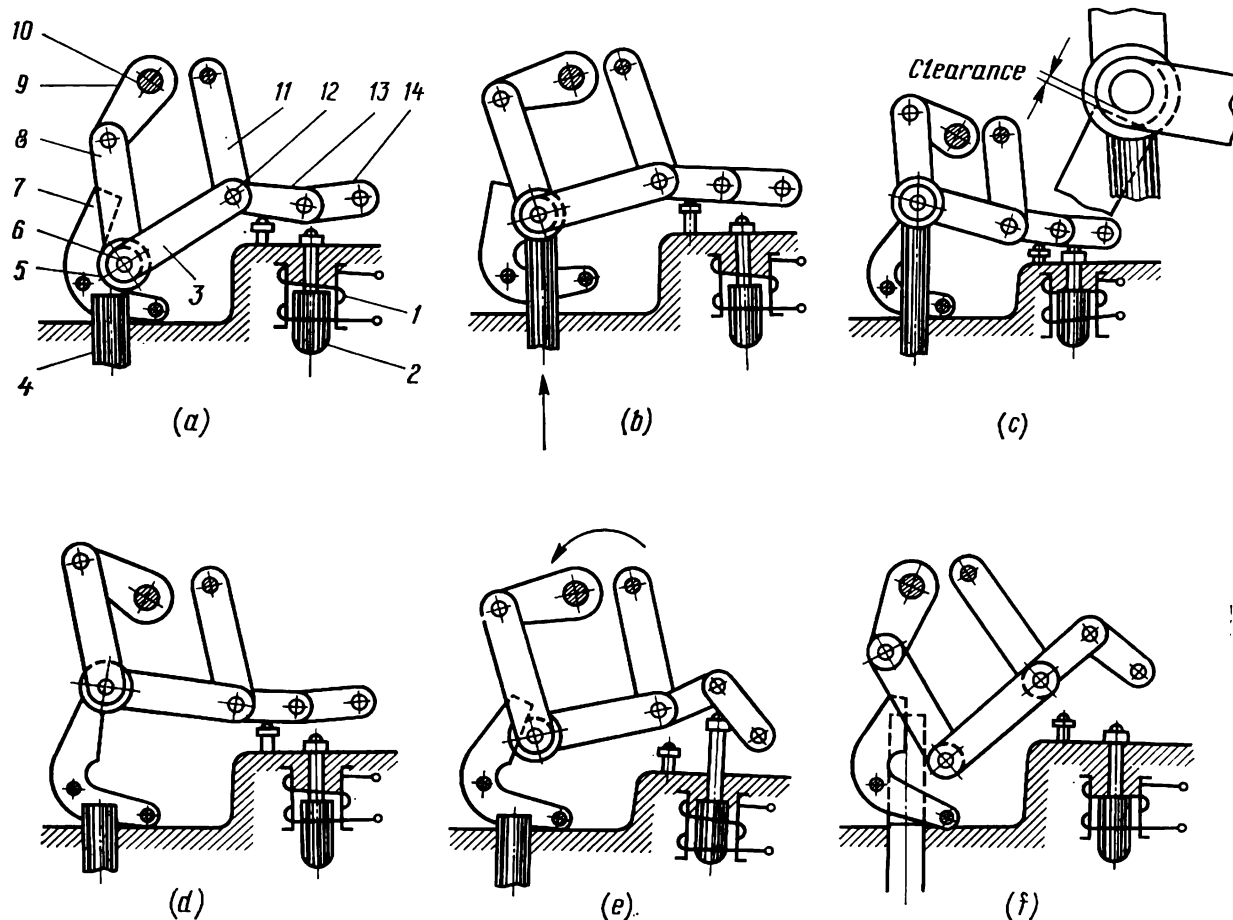


Fig. 154. Linkage of operating mechanism $\Pi C-10$ in different positions

a—off-position (the operating mechanism is ready for closure); *b*—while being closed; *c*—on-position (the core is drawn in); *d*—on-position (the core is returned to original position); *e*—while being opened; *f*—circuit breaker is opened. operating mechanism is not ready for closure; 1—breaking solenoid; 2—core; 3, 8, 9—levers; 4—rod; 5—roller; 6, 12—pins; 7—latch; 10—shaft; 11, 13, 14—collapsible levers

construction, light mass, easy adjustment of the breaker and operating mechanism during installation. One of the most important features of the $\Pi9-11$ operating mechanism is provision for special auxiliary contacts that function to prevent jumps in the event of closing the circuit breaker to a short-circuited network. As compared to the $\Pi C-10$ operating mechanism, the power requirement of the $\Pi9-11$ operating mechanism is 35 to 40 per cent lower.

Basic mounting dimensions and methods of installation of electromagnetic operating mechanisms are given in Fig. 156.

Three-phase a.c. operating mechanisms have recently found application for the control of circuit breakers. These operating mechanisms are noted for better characteristics at the same pulling forces as compared to the ПС and ПЭ operating mechanisms.

The moving part of the electromagnetic system of the three-phase operating mechanism (Fig. 157a, b, c, d) consists of three L-shaped stacks built up of transformer steel laminations, 0.35 mm thick, arranged symmetrically around a rod 5. The operating mechanism is coupled with the circuit breaker via a fork and an articulated joint.

To the advantage of the three-phase a.c. electromagnetic mechanism, as compared to d.c. ones, is the fact that it does not require an expensive storage battery and runs unattended, its pulling characteristics can be adjusted within a wide range, the mechanism is simple in operation and maintenance.

The installation of manual, spring-loaded, counterweight-actuated, and electromagnetic operating mechanisms shall be carried out in compliance with the project, pertinent instructions supplied by the manufacturer, and Regulations for Electrical Installations. The procedure is as follows.

An operating mechanism delivered on site of installation shall be unpacked and examined, checked for missing standard items and for damage. Holes for fastenings shall be marked out by means of a template and drilled. The operating mechanism is secured in position and checked manually for easy making and breaking. If the operating mechanism linkage is coated with slushing grease, it must be flushed out with paraffin oil, its rubbing surfaces must be coated with solid oil (in warm seasons) or with nonfreezing lubricant (in nonheated premises at an ambient temperature below -5°C). The rubbing surfaces of the friction coupling in the ПРБ operating mechanism must never be lubricated. This done, the distance from the operating mechanism to the circuit breaker must be measured and a shaft for their coupling be made. A piece of gas- and water-pipe of the desired length and appropriate wall thickness can be used for the purpose. The shafts of the breaker and operating mechanism are joined by means of levers, forks, and couplings.

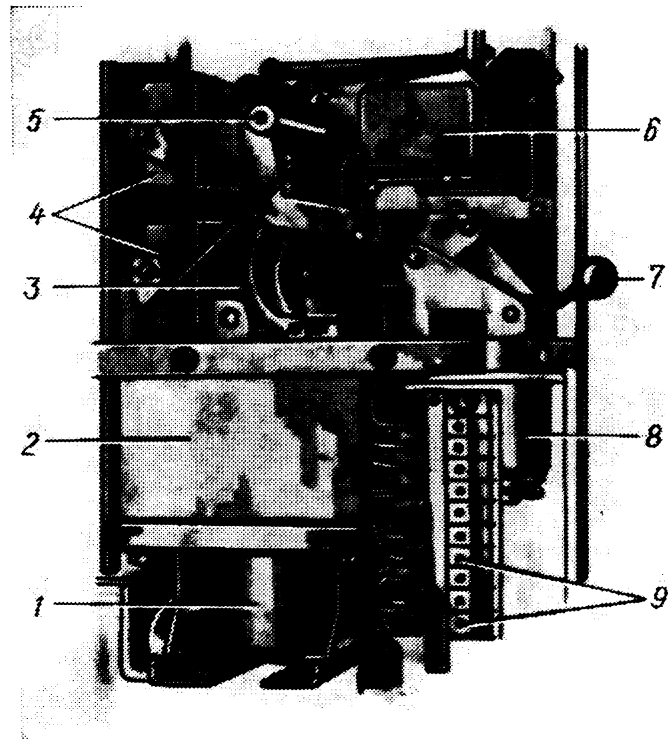


Fig. 155. Electromagnetic operating mechanism ПЭ-11

1—making magnet core; 2—making magnet circuit; 3—latch; 4, 6—auxiliary signaling contacts; 5—operating mechanism shaft; 7—manual control handle; 8—breaking magnet; 9—terminals for the connection of control, signaling, and relay protection circuit leads

When a coupling is used, taper pins measuring at least 4 mm in the middle portion are required. An operating mechanism whose shaft is fitted with a fork shall be coupled to the breaker shaft via an articulated joint. Then the operating mechanism shall be closed manually to check it for reliable latching by the holding mechanism.

The operating mechanisms are supplied by the manufacturer fully adjusted; careless handling in transit or in storage, however, may cause damage to some

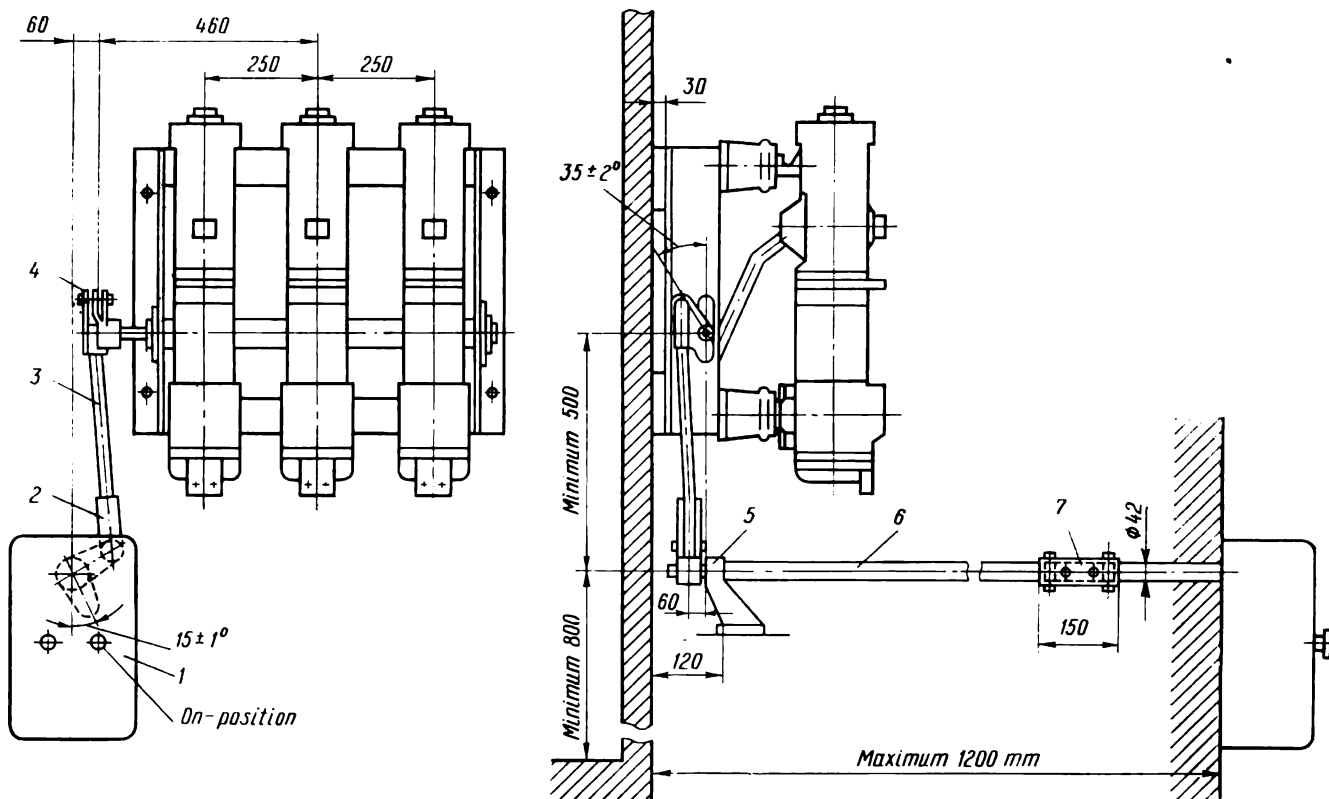


Fig. 156. Installation of BMII-10 circuit breakers with electromagnetic operating mechanisms ПС-10 and ПЭ-11

1—operating mechanism; 2—fork; 3—operating rod; 4—lever; 5—bearing; 6—shaft; 7—coupling with tapered pins

of their parts and make them maladjusted. When this is the case, the operating mechanism will need adjustment on site of installation.

Electricians in charge couple the operating mechanism with the associated circuit breaker and check them for reliable functioning, taking measures to ensure a proper and reliable operation of all their elements.

The adjustment of the operating mechanism, after it has been installed in position and connected to the circuit breaker, is to be carried out as follows. Close the circuit breaker and the operating mechanism and make sure that the latter reliably holds the breaker in the on-position. Slowly open the circuit breaker and in the action check the operating mechanism linkage for proper operation and interaction between its separate elements in two or three intermediate positions. Open the circuit breaker and the operating mechanism. If necessary, vary the angle of

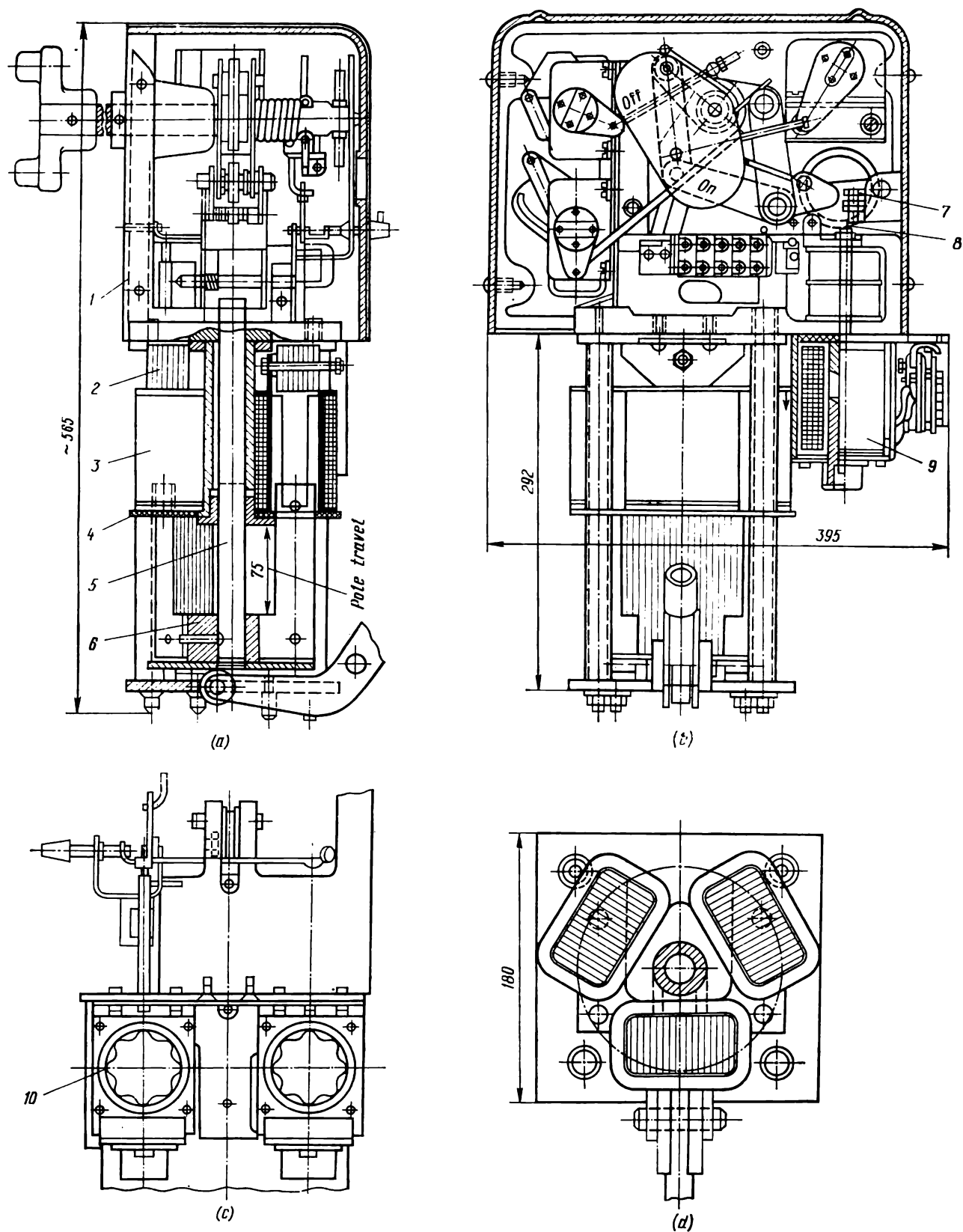


Fig. 157. Three-phase a.c. electromagnetic operating mechanism (with case removed)
a—side view; *b*—front view; *c*—disconnecting gear; *d*—arrangement of electromagnets; 1—operating mechanism bracket; 2—ribbon core; 3—electromagnet coil; 4—plate; 5—rod; 6—shell; 7—shackle; 8—auxiliary pawl; 9—undervoltage relay; 10—overcurrent relay

turn of the levers and the length of the operating rods until the specified separation between the movable and stationary contacts of the breaker is obtained in the off-position. Moreover, a sufficient overtravel of moving parts beyond the extreme position must be ensured when the breaker is being closed.

The ППМ and УПП operating mechanisms are furnished with a spring winder composed of an automatic reduction unit driven by a type МУН 0.2-kW motor. In mounting these operating mechanisms, check the motor and reduction unit shafts for alignment and for easy rotation; bear in mind that any misalignment of these shafts or excessive friction in the gear drive may cause abnormal operation of the winder and even failure of the motor.

The winder shall be checked at a normal preset tension of the closing springs.

In recent years a general recognition was gained by the type ВМН-10П circuit breakers with a built-in operating mechanism. These breakers are of smaller bulk as compared to those with separately mounted operating mechanisms. However, they are more difficult to adjust under installation conditions due to a more complicated mechanical design of these devices.

Some elements of the built-in operating mechanisms (Fig. 158) are arranged so that in winding the operating springs the latter may cause spontaneous closure of the circuit breaker. This may occur, for example, after the manual closure of the breaker at a maximum tension of the operating springs 8. When the springs are excessively tensioned, the shaft 9 may turn in closing through an angle greater than 360 deg and, as the manual making button 6 is depressed, the lever 2 will not be locked in the original position by the latching mechanism 1. As a result, the operating mechanism shaft 9 will turn during winding of the operating springs 8 and slowly close the circuit breaker by means of its cam 12. In this process the breaker will not close completely as the torque on the shaft 3 of the breaker afforded by the operating springs of the operating mechanism will be lower than the static closing torque of the breaker at the end of the closing operation (at the portion of the movable contact rod travel in the cluster socket contact). Incomplete closure of the breaker will cause overheating of its contacts due to working currents carried by its contact system, with the result that the breaker may fail.

In order to eliminate spontaneous closure of the breaker during winding of the operating springs, the following measures must be taken. Wind up the operating springs 8 by means of the winder 7 up to the maximum permissible value. In the action, the pin 10 on the lever of the shaft of auxiliary contacts 13 indicating the position of the operating springs must assume the extreme lower position* in the opening of the disk 11. Then close the breaker manually with the button 6 and release it only after the breaker has fully closed and the operating mechanism shaft has stopped rotating. The operating mechanism shaft must not turn through an angle exceeding 360 deg, otherwise the breaker may spontaneously close during winding of the operating springs. Spontaneous closure of the ВМН-10П circuit breakers during winding of operating springs may also happen in case the lever 5 does not engage the holding latch 4 of the holding linkage. That is why, in closing

* The pin 10 positioned on the rim of the disk 11 points to overtensioning of the operating springs 8.

the breaker by the button 6 at a maximum tension of the operating springs, check to see that the lever 5 engages the holding latch 4 after the breaker is fully closed.

The above-specified check of the built-in operating mechanism of the BMII-10II circuit breaker shall be carried out at least five times in the course of adjustment.

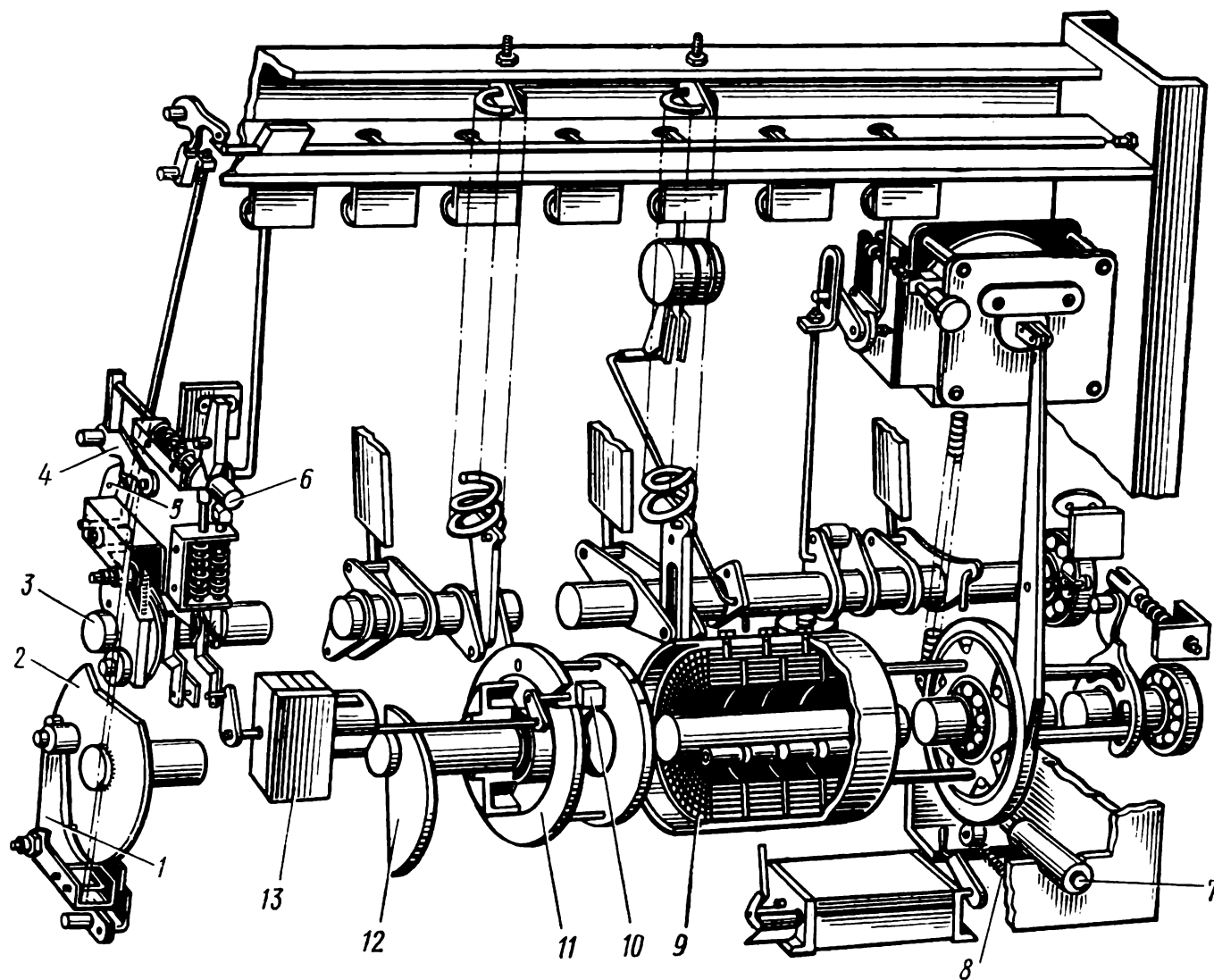


Fig. 158. Mechanical diagram of operating mechanism built into circuit breaker BMII-10II in on-position and with wound springs

1—on-operation latching mechanism; 2, 5—levers; 3—circuit breaker shaft; 4—holding latch; 6—manual closing button; 7—manual spring winder; 8—closing spring; 9—operating mechanism shaft; 10—pin; 11—disk; 12—cam; 13—auxiliary contacts

In mounting the operating mechanisms of all types do not:

- (a) change the preset tension of the springs;
- (b) use self-made items instead of factory-made complicated parts;
- (c) file off or scrape the working surfaces of the linkage elements.
- (d) perform operations prohibited by the manufacturer's service manuals;

(e) neglect the manufacturer's instructions for the installation, adjustment, and test of the operating mechanisms.

Prior to starting the installation, take the following measures to exclude accidents:

(a) place the operating mechanism in the off-position and take measures excluding a spontaneous closure of its separate elements (for example, fit wooden wedges under the moving parts of the mechanism) prior to starting the installation, attachment, cleaning, and lubrication of its linkage;

(b) prior to disassembling or lubricating the mechanism linkage, disconnect the operating mechanism from the breaker, and the remote-control, relay-protection, and automatic-control circuits from its relays and electromagnets;

(c) perform checks for normal functioning of the operating mechanism in conjunction with the circuit breaker only after all the personnel leave the cubicle or chamber accommodating the breaker;

(d) do not open or close the circuit breaker remotely unless you have obtained the permission from the dispatcher on duty, or do this work under the supervision of the crew leader, foreman, or the engineer in charge of installation.

An overall regulation and adjustment of the operating mechanism in conjunction with the associated circuit breaker and their functioning in conjunction with protective and automatic-control gear shall be carried out after installation by the personnel of appropriate services of the chief power engineer department of the industrial plant, power system, or special agency.

9.5. Installation of High-Voltage Fuses

A high-voltage fuse is meant to protect the electrical equipment of an electrical installation rated over 1,000 V upon the occurrence of inadmissible overloads and short circuits.

The protective element of the fuse is a fuse link inserted in series with the circuit being protected.

The fuse depends for its operation on the ability of its fuse link to blow out under the effect of overload or short-circuit currents, which heat it to excessive temperature, and to open the circuit of the equipment being protected after the arc set up in the course of melting of the link metal is fully extinguished. The time required for the fuse link to blow out depends on the magnitude of current it passes. This dependence is called the time-current or protective characteristic of the fuse link, which determines the time delay in the interruption of abnormal currents.

The magnitude of current capable of melting the fuse link depends on the length, material, cross-sectional area, the shape of the fuse link, and also on the design of the fuse, ambient temperature, and some other factors.

When the fuse carries working currents, its fuse link, like any other conductor, heats, but the structure of its material is retained. A fuse link carrying currents lower than the rated value can work for a long period of time.

If an overload or, moreover, short-circuit current flows through the fuse, its link melts and turns into a liquid and then into a gas state. An arc jumps the gap

between the electrodes, its burning time and rate of complete suppression depending on the construction of the fuse.

The blow-out time of the fuse link can be found from the equation

$$t = t_1 + t_2 + t_3$$

where t_1 is time required for heating the fuse link from the working temperature to its melting point; t_2 is time required for melting the fuse link metal; t_3 is arcing time up to the interruption of the electric circuit.

The fuses must be reliable, stable, and selective in operation. It means that the fuse link must sustain continuously the rated current, must not blow out at short-time overloads, reliably interrupt abnormal currents, and upon the occurrence of short circuit in any point of the electric circuit it must disconnect only the section of the circuit being protected. In the latter case, the fuse link of the fuse closest to the point of short circuit on the supply end must blow out.

Fuses are characterized by rated and limiting no-damage currents, and fuse links are characterized by rated currents.

The rated current of a fuse is the current sustained by its current-carrying parts. The rated current of a fuse link is the current that can be sustained by the link for an infinitely long time.

The rated currents are indicated on the current-carrying parts of fuses and on the contact members of fuse links.

The limiting no-damage current or breaking capacity of the fuse is the maximum current or, respectively, short-circuit capacity that can be interrupted (cleared) by the fuse when its link blows out.

The rated voltages of fuses and the rated currents of their links must comply with the rated currents and voltages of electric circuits being protected. The operating conditions of fuses are impaired if this requirement is not met.

A fuse rated at a lower voltage may cause short circuit and fail. A fuse rated at higher currents and voltages will not afford the desired protection as its characteristics do not comply with those of the circuit under protection. In order to ensure the reliable protection, the time-current characteristic of the fuse link must be slightly lower than the characteristic of the equipment being protected.

The current at which the fuse link blows at the moment it reaches the steady state temperature is called the minimum fusing current. The fuse link does not blow at the rated current when its minimum fusing current is slightly higher than the rated value.

The time-current characteristic of the fuse depends to a certain extent on the condition of its fuse link. Fuse links of fuses delivered on the installation site are often covered with oxide film due to a long-time storage under abnormal conditions. The sectional area of the fusing element in such an oxidized link decreases, which affects the fuse characteristic.

The maximum current interrupted by the fuse link I_{link} must be equal to or higher than the maximum rated short-circuit current handled by the circuit under protection. If this requirement is not complied with, the arcing time increases and this may cause breakdown of the fuse.

Most widely used for enclosed electrical installations rated 6 and 10 kV are the type ПК and ПКТ fuses.

The type ПК fuse (Fig. 159a) consists of a steel base 1 and two support insulators 5 carrying two contact clips mounting a cartridge 3. The contact clips 2 are fitted with latches that hold the cartridge in position when electrodynamic forces are built up in the clips and in the current-carrying parts at the moment they pass

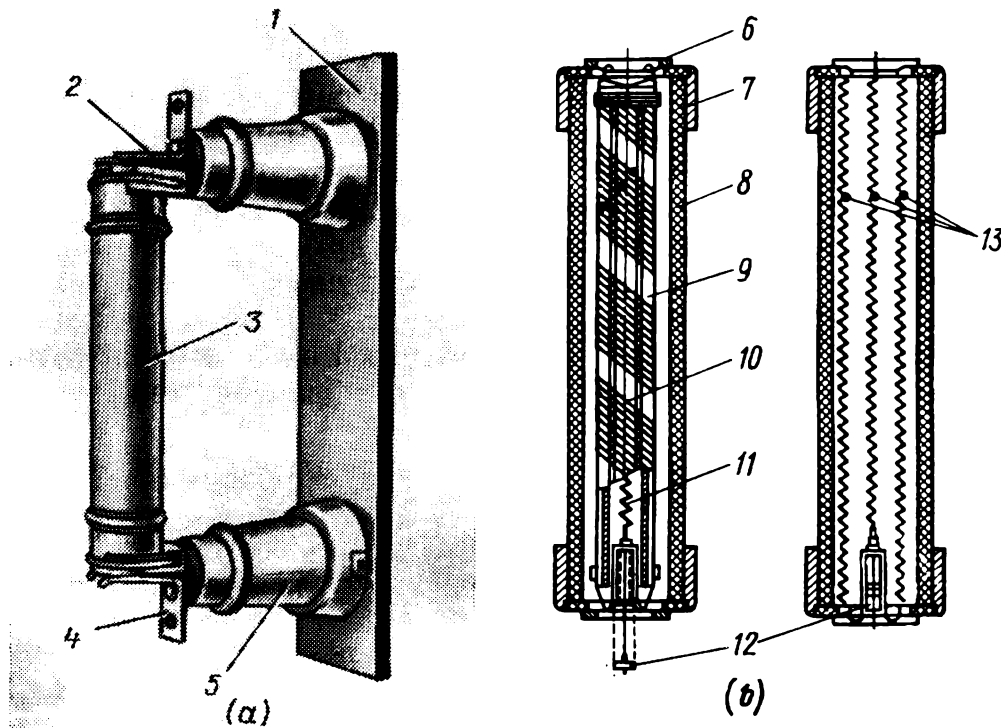


Fig. 159. High-voltage fuse ПК

a—general view; *b*—fuse cartridge with a ceramic bar (fuse at left) and without the bar (fuse at right); 1—base; 2—fuse contact clip and latch; 3—cartridge; 4—binding post; 5—support insulator; 6—cover; 7—brass end cap; 8—porcelain casing (shell); 9—bar; 10—fuse link; 11—blow-out indicator wire; 12—blow-out indicator; 13—tin beads

short-circuit currents. The terminal bolt 4 of the contact clip 2 is used to connect the substation switchgear buses to the fuse.

The fuse cartridge (Fig. 159b) is a tubular porcelain casing 8 carrying brass end caps 7 at the ends with covers 6. The casing accommodates a fuse link 10 consisting of copper wires covered with silver. For rated currents of up to 7.5 A, the fuse link wires are wound on a ceramic bar (core) 9; for currents higher than 7.5 A, they are made in the form of a coil inserted into the porcelain casing.

The type-ПК fuse link wire for rated currents of up to 7.5 A is of the same diameter over the entire length, but for currents over 7.5 A it has different diameters. The fuse links of this graded cross-sectional area have much better characteristics. These links do not melt and evaporate simultaneously. The section of a smaller area melts first, and that of the larger area the last. In this way, the

length of the section being broken is reduced, causing a reduction in the surge voltages due to blowing-out of the fuse link. A non-simultaneous fusion and evaporation of the fuse link makes it possible to reduce the surge voltages to 250 per cent of the working voltage. The fuse link is made of several parallel wires.

Such an arrangement improves heat transfer and reduces the total sectional area of the fuse, thereby improving its cooling conditions. Hence, an electric arc arising in several parallel ducts is more readily extinguished.

To reduce the melting point of the fuse link, tin beads 13 are soldered onto its wires. The melting point of the fuse link is reduced due to the so-called metallurgical effect consisting in that the tin melts quicker than the copper of the wire, penetrates into the material of the wire element and lowers the melting point of the latter.

The cartridge of the ПК fuse is filled with fine-grain quartz sand containing about 99 per cent of pure dry quartz. So, the fuse link is surrounded within the cartridge with a medium whose fine-grain structure affords a rapid deionization of the arc in the space between the grains of quartz and penetration of metal vapours deep into the sand.

The ПК fuse is a current-limiting protective device because the short-circuit current is interrupted upon the fusion and evaporation of the fuse link, which takes place much earlier than the current reaches its maximum and not during its natural flow through zero.

The fuse cartridge is provided with a blow-out indicator 12 that consists of a metal bush, a spring, an indicator wire 11, and a head with a hook. The metal bush accommodating the spring is mounted on the cartridge cap. One end of the spring is connected to the bush and the other to the indicator head with a hook, the latter engaging the indicator wire. The spring is held in the compressed state.

The blow-out indicator operates as follows. The indicator wire melts together with the fuse links and releases the spring which is ejected from the fuse together with the head, thus giving a visible indication that the fuse is blown.

The type ПКТ fuses are designed for the protection of potential transformers. The fuse link of the ПКТ fuse is wound on a ribbed bar and consists of constantan wires. This fuse is not provided with a blow-out indicator, and under operating conditions its fuse link is checked by means of a magneto and bell or by a test lamp.

The fuse links for the ПК fuses are available in the following current ratings: 2, 3, 5, 7.5, 10, 15, 20, 30, 40, 50, 75, 100, 150, 200 and 300 A.

Fuses for different rated voltages are distinguished by the length of their cartridges, and for different rated currents also by the diameters of the cartridges and caps and the construction of contact clips. The ПК fuses rated at 6 kV, 75 A and higher, and those rated at 10 kV, 50 A and higher have coupled cartridges. Fuses for currents exceeding 200 A at 6 kV and for currents higher than 150 A at 10 kV are furnished with four cartridges. Cartridges of the ПКТ fuses for potential transformers rated up to 10 kV are of a single size.

Prior to installing the ПК and ПКТ fuses, check them for the following:

- (a) defects on insulating parts, contact clips, fittings, fastenings;
- (b) volume and density of filler;

- (c) sealing of the cartridge incorporating the fuse links;
- (d) condition of the fuse link and its rating that must comply with the rated current of the cartridge and fuse;
- (e) condition of the blow-out indicator;
- (f) condition of the steel spring clips and their proper clipping of contact parts;
- (g) fixation of cartridges in the contact clips of the fuse.

The fuses are mounted directly on a wall, a steel frame, a base made of channel bar or two angle plates. In this case, the longitudinal axes of each pair of contact clips must coincide accurate to ± 0.5 mm. The cartridges must enter the contact clips of the fuses easily and without misalignment. Retainers provided at the clips must be tightly pressed to the butt ends of the cartridge caps so as to limit the cartridge motion in the vertical direction. The blow-out indicators in the working position must face down and be easily observed by the attending personnel. The latches must reliably hold the cartridge in position. The cartridges must fit tightly in order to prevent their dropping out on occurrence of electrodynamic forces developed by a flow of short-circuit current through the fuse.

The switchgear buses must be connected to the fuse terminals so as not to cause additional mechanical forces on the contact clips which may damage them.

The fuses are earthed through an earthing bus connected to the flanges of support insulators, a frame, or a metal structure that supports them. The earthing conductor is either connected to an earthing bolt or attached by welding.

9.6. Installation of Reactors

The reactor is a current-limiting device composed of a coil possessing a high inductance and a very low resistance.

The reactor limits short-circuit currents to improve operating conditions for the electrical equipment of substations and to maintain a definite voltage level across the switchgear buses on occurrence of short circuits.

One of the basic characteristics of the reactor is its reactance x_r in per cent of voltage drop across the reactor when its winding carries rated current. The reactance x_r is referred to as percentage reactance which characterizes the current-limiting ability of the reactor.

The reactors must meet the following requirements;

- (a) voltage surges must not cause breakdown of the reactor turn-to-turn insulation and winding-to-earth insulation, or partial creeping discharge;
- (b) the reactor must have a sufficiently high thermal and transient stability;
- (c) power loss in the reactor must be brought to a minimum so as not to cause its heating above specified values;
- (d) the reactor coil must be wound so as to exclude turn-to-turn fault whatever conditions may occur (surge voltages, overheating, electrodynamic forces);
- (e) the winding wire must have a sufficient mechanical strength so as to exclude residual strain or breakage of turns on occurrence of short circuits;
- (f) the reactor cell shall be made of such a material and designed so that it can withstand high temperatures and heavy electrodynamic forces;

(g) multiphase reactors must sustain forces developed between phases on occurrence of short circuits.

Reactors are distinguished according to their application as bus and feeder reactors. Bus reactors connected between bus sections are used to limit the short-circuit current of the entire installation. Feeder reactors function to limit short-circuit currents through the line under protection and to maintain the desired voltage level on the electrical installation parts mounted in front of the reactor.

According to their mechanical design, reactors are classified as air-core and oil-immersed reactors. Air-core reactors are provided with dry insulation cooled by air. Oil-immersed reactors are cooled by oil which functions at the same time as the reactor insulation.

Cast-in-concrete air-core reactors of the PB type with copper wire windings and PBA with aluminium wire windings are used in electrical equipment rated 6 and 10 kV.

The cast-in-concrete reactor (Fig. 160*a, b*) consists of a winding 1 and ten radially arranged vertical columns 2 mounted on porcelain support insulators 3. The concentric winding is secured in concrete columns, and its starting and finishing leads are brought out and connected to binding posts 5 embedded in the columns. Fitted in each column are two through tie rods 4 with threaded ends. The lower ends of the tie rods receive the heads of insulators 3 and the upper ones are used to hold the flanges of the upper-phase support insulators in the case of a vertical arrangement of phases.

The cast-in-concrete reactor has a special handling facility in the form of a sprocket with a central bar provided with an eye to receive the hook of a hoist.

The type PB cast-in-concrete reactor may be accepted for installation provided it has a nameplate and QCD brand, is free from cracks and chips on support insulators, the concrete and varnish coat of the columns are free from fractured parts, the insulators are reliably reinforced and securely attached to the columns, the winding turns are not warped and their insulation is in good condition, and the through bars are reliably fixed within the columns.

The winding-to-bar insulation resistance shall not be lower than 0.5 MΩ.

It may happen that the reactor delivered to the installation site was long exposed to the open air. The varnish coating on the columns of such a reactor is damaged, its insulation is moistened and wants drying.

For drying the reactors, one of the following methods can be used:

(a) by hot air forced from blowers into the chamber accommodating the reactor; the chamber must be lined inside with a refractory material (asbestos sheets, slate, or roofing iron placed on felt) and have exhaust ports to evacuate evaporating moisture;

(b) by passing through the winding alternating or direct current of a magnitude sufficient to heat it to a temperature of 85 to 90°C;

(c) by induction loss method when a cast-iron tube 250 mm in diameter is inserted into the winding in the centre of the reactor, the tube length being equal to the winding height, then a welding transformer is connected to the winding and a current of a magnitude sufficient to maintain a temperature of 90 to 100°C is applied to the winding terminals.

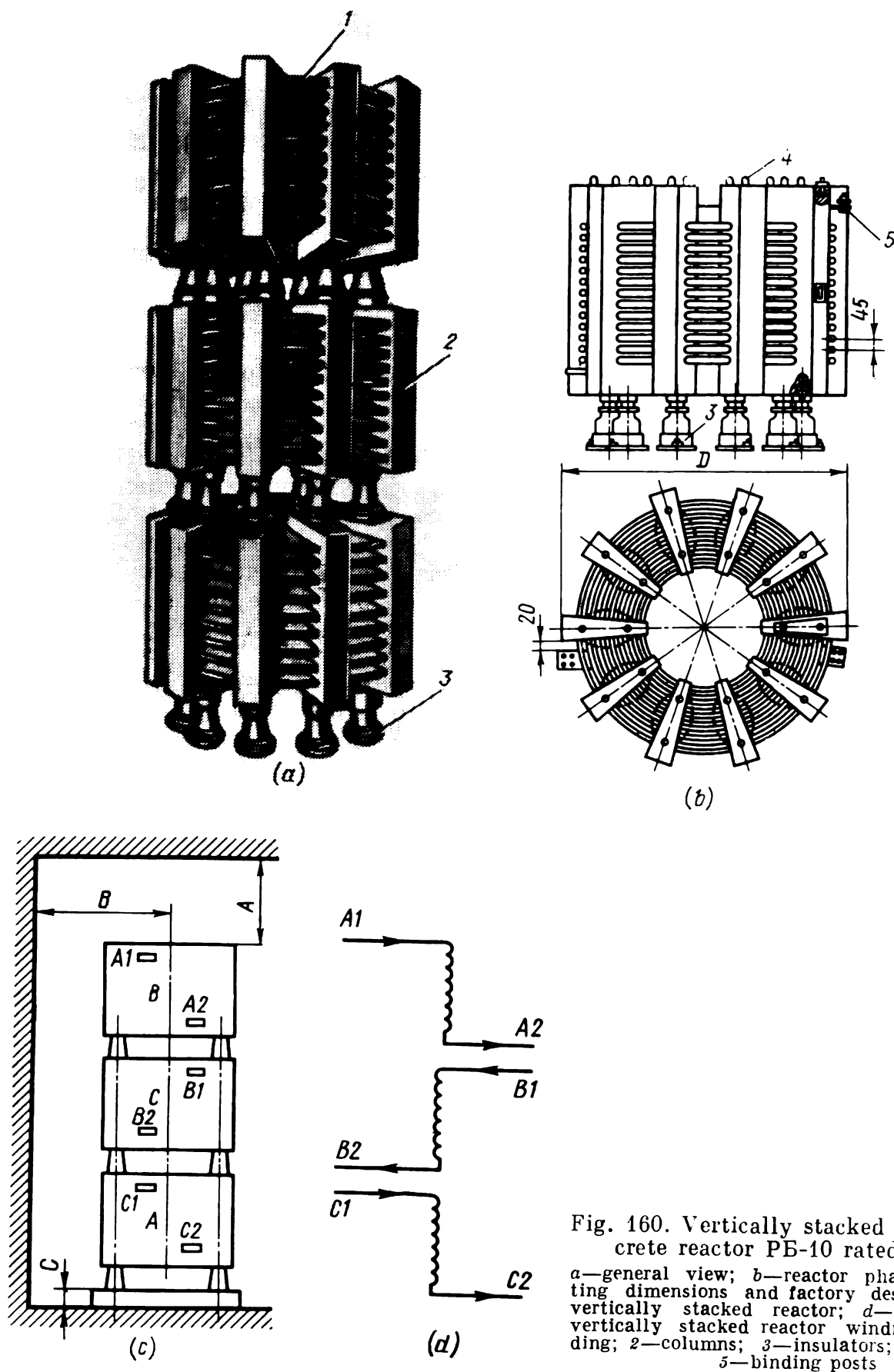


Fig. 160. Vertically stacked cast-in-concrete reactor PE-10 rated 10 kV
 a—general view; b—reactor phase; c—mounting dimensions and factory designations for vertically stacked reactor; d—connection of vertically stacked reactor windings; 1—winding; 2—columns; 3—insulators; 4—tie rods; 5—binding posts

The drying temperature is controlled by thermometers or the thermocouples installed in the winding top, middle, and bottom.

After drying-out of the reactor windings, the concrete columns should be coated with two layers of natural drying oil, each layer being allowed to dry before the next is applied so as to obtain a solid film on the concrete surface.

The reactor may be accepted for installation only after all troubles are eliminated and normal insulation resistance of its winding is obtained.

The reactors shall be mounted in dry premises in full compliance with the manufacturer's pertinent instructions, Regulations for Electrical Installations, and dimensional drawings and tables (see Fig. 160c and Table 42).

Table 42

**Mounting Dimensions of Cast-in-Concrete
Reactors Rated 6 to 10 kV and Installed in Chambers**

Designation of dimension	Dimensions, mm (Fig. 160b)
<i>A</i>	$0.5D-130$
<i>B</i>	$D-120$
<i>C</i>	$0.5D-325$

Note. *D* is the outer diameter of the reactor over concrete columns.

Steel structures located in close proximity to the cast-in-concrete reactors must be free from closed circuits because the magnetic field of the cast-in-concrete reactor closes through the air surrounding the reactor, and if closed conductors are found in this field, heavy currents may be induced in the reactor that may heat it to an inadmissible temperature.

The reactors may be installed horizontally or vertically.

Vertical arrangement is more frequently used. In vertically stacked reactors, it is essential to provide such a phase sequence at which the turns of the middle phase are differential to those of the upper and lower phases (Fig. 160d). When this condition is satisfied, forces developed between the windings of two adjacent phases due to short circuits cause attraction rather than repulsion between the phase windings, so that the phase insulators are subjected to compressive instead of tensile stress, that is, operate under more favourable conditions.

All the reactor phases are stacked and mounted in accordance with the factory designations they bear: B is the upper phase, C the middle, and H the lower phases. Buses are connected to the reactor also in accordance with factory designations, where A1, B1, C1 are input terminals and A2, B2, C2 are output terminals.

The reactor phases must be hoisted and mounted with particular care by means of channel bars and catching ropes. After all the installation jobs are completed, all metal pieces and tools must be removed from the premises where the reactor is installed, otherwise they may be attracted to the energized reactor and damage its winding.

The flanges of the lower support insulators of the lower phase and those of the upper strut insulators of the upper phase of a vertically stacked reactor must be earthed by connecting them to the general earthing system through steel strips measuring at least 30×4 mm.

9.7. Installation of Lightning Arresters

Lightning arresters are used to protect electrical installations against surge voltages.

Surge voltages are any abnormal voltages that may cause breakdown of insulation of electrical equipment. Surge voltages may result from switching disturbances in the electrical installation circuit or from lightning strokes.

Switching surges amounting sometimes to 300 or 400 per cent of the peak value of the electrical installation working voltage occur due to a change in the operating conditions of electrical installations, such as connection, disconnection, or sudden variation of load, breaking of high-inductance or high-capacitance circuits, disconnection of short-circuit currents, or earthing of one of supply phases through an arc, and other similar cases.

Switching surges do not exceed test voltages applied to the electrical equipment in checking its insulation strength and are usually short-time, with the exception of arcing earth.

Atmospheric surges result from direct lightning strokes affecting the electrical installation or nearby lightning discharges. Most dangerous are atmospheric surges resulting from discharges directly through the line or substation that cause the flow of heavy currents and result in increased voltages, tens of times higher than its rated voltage. Atmospheric surges most frequently arrive from the side of the overhead power transmission lines; that is why they are most dangerous for the insulation of all the elements of the electrical equipment connected to these lines.

The electrical equipment of substations is protected against atmospheric surges by means of the type PBII and PBC lightning arresters which function to divert surge voltages to earth. The protective action of the lightning arrester consists in that it reduces the surge voltage amplitude to a safe value.

The type PBII vilite arrester shown by Fig. 161a consists of a series-gap assembly 4 and a stack of vilite disks (working resistor) 5, all accommodated in a porcelain casing (shell) 6. The series-gap assembly consists of a number of series-connected spark gaps each composed of two shaped disks with a micanite ring fitted between them.

The vilite disks are based on carborundum granules noted for low resistivity. The surface of carborundum granules is coated with a very thin film of silicon oxide. The film resistance abruptly drops as soon as the voltage applied rises, thereby limiting the voltage drop.

The PBII lightning arrester is not furnished with shunting resistors.

The series-gap assembly is arranged on the top of the casing and compressed by a spring 3. A stack of vilite disks placed at the bottom of the casing makes up the working resistor of the arrester. The number of spark gaps in the assembly and of vilite disks in the stack depends on the rated voltage of the arrester.

Surge voltages cause a breakdown of a spark gap and the entire voltage is applied to the vilite disks whose resistance abruptly decreases, with the result that current starts flowing through the arrester. When this is the case, the line is earthed and the voltage decreases to the working value while the vilite disk resistance rises and interrupts the current flow. The resultant arc is suppressed in the spark gap of the arrester.

The electrical equipment of substations is also protected by the type PBC lightning arresters.

The PBC arresters illustrated by Fig. 161b are distinguished from the PBII type by the shape of their casing, and offer better characteristics due to a shunting

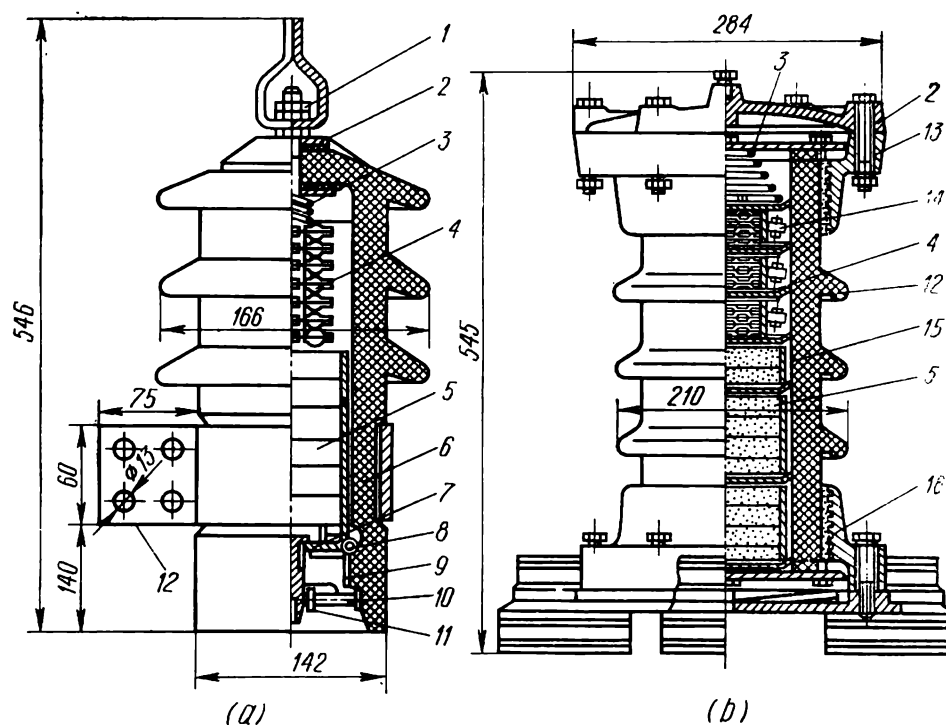


Fig. 161. Substation 10 kV lightning arresters

a—vilite type PBII; *b*—nonlinear-resistance type PBC; 1—bushing; 2, 9—rubber gaskets; 3—spring; 4—series-gap assembly; 5—vilite disks; 6—porcelain casing (shell); 7, 10—diaphragms; 8—stop; 11—earth terminal; 12—arrester attachment clip; 13, 16—flanges; 14—shunting resistors; 15—ceramic coat

resistor 14 that functions to uniformly distribute voltage across the spark gaps.

As soon as the spark gaps are punctured, the so-called power-frequency follow current rushes after the surge wave under the effect of the working voltage. In addition to maintaining the arc burning in the arrester, which is in itself inadmissible, this power follow current affects the vilite disks for many half-cycles and heats them to an abnormal temperature.

The flow of the power follow current through the arrester during many half-cycles may also destruct the spark gaps. Therefore, the spark gap is designed so that the follow current is cut off at the first zero of the half-cycle.

The spark gaps of the PBII arresters, as has been already mentioned, are not provided with shunting resistors, and therefore the voltage between separate gaps

is distributed unevenly since the distribution depends on their inherent capacitances. This nonuniformity is good for operating the arrester at surges as it aids in its puncture. On the other hand, this nonuniformity has a detrimental effect on the arrester when operated at commercial-frequency voltages and at switching surges, and also in the course of voltage recovery upon arc interruption. Under these conditions, equal voltage distribution across the spark gaps is therefore more desirable. In the PBC arresters, equal voltage distribution is afforded by a non-linear resistor that shunts the spark gaps in such a manner that at surges this distribution remains still non-uniform. Resistors are made of horseshoe-shaped ceramic plates embracing a small number of spark gaps.

The PBC arrester is called a nonlinear-resistance arrester as at surge currents its resistance suddenly drops giving way to a rather heavy current at a relatively low voltage drop across the resistor.

The porcelain casings of the PBII and PBC arresters are sealed with ozone-resistant rubber gaskets 2 and 9, a diaphragm 10, and by reinforcing the flanges 13, 16 to prevent dust and moisture penetration, which may impair the arrester characteristics.

Lightning arresters delivered to the installation site shall be examined and checked for:

- (a) the condition of porcelain shells (cracks, chippings, swelling porcelain, etc.);
- (b) the condition of reinforcing joints between the porcelain shell and the flange, the condition of the varnish coat on the reinforcing joint;
- (c) fixation of internal parts (to be checked by rocking and shaking the arrester);
- (d) quantity and condition of fastenings.

The lightning arresters must be installed on supporting structures in a vertical position and arranged so as to exclude any accidental contact with them. In the switchgear cubicles of enclosed substations they are to be mounted in special chambers. Buses connected to the lightning arresters must not exert pressures on the latter in excess of 25 kgf.

Prior to mounting lightning arresters it is necessary to check clearances between their current-carrying parts and other elements of the electrical installation (earthed and current-carrying parts of other devices, walls, guards, etc.) for compliance with specified values.

Safety clearances for lightning arresters mounted in enclosed substations shall be at least as follows:

100 mm for an electrical installation rated 6 kV;

125 mm for an electrical installation rated 10 kV.

It is good practice to connect the lightning arresters through isolators so as to facilitate their maintenance, tests, and disconnection in cold seasons.

The lightning arresters must be earthed with rigid buses routed over the shortest possible distance. Metal surfaces of the arresters are coated with moisture-resistant paint.

Newly installed lightning arresters shall be tested prior to being placed in operation for breakdown voltage and leakage current.

9.8. Installation of Power Transformers

The power transformer is a static machine dispensing with rotating parts, which functions to transform alternating current of one voltage into alternating current of a different voltage.

Each transformer carries a nameplate made of weather-resistant material and attached to the transformer tank at an easy-to-observe place. According to the USSR State Standard GOST 11677-65, it bears the transformer ratings applied by engraving, etching, stamping, or by any other method, ensuring good visibility and durability of inscriptions.

The nameplate data of power transformers are transformer type, rated capacity (rated, tap, and impedance voltages), number of phases, connection and vector group of windings, frequency, duty rating (short-time or continuous), method of cooling, indoor or outdoor installation, mass of transformer and its core-and-winding assembly. The nameplate also includes the name of manufacturing plant, year of manufacture, and the serial number of transformer. The serial number of the transformer is also stamped on the transformer tank (under the nameplate), cover (at phase A high-voltage bushing), and on the upper shoulder of the yoke beam.

Type designations of transformers are specified by GOST 11677-65 and consist of letters and numerals showing the following:

The first letter indicates the number of phases (O—single-phase, T—three-phase); the next one or two letters show the type of cooling (M—oil-immersed, self-cooled; Д—oil-immersed, forced-cooled, self-oil-circulation; ДЦ—oil-immersed, forced-cooled, forced-oil-circulation; MB—oil-immersed, self-water-cooled, self-oil-circulation; Ц—oil-immersed, water-cooled, forced-oil-circulation; C, C3, ЦГ—dry-type self-air-cooled, in open, enclosed, and hermetically sealed design, respectively; H or HD—noncombustible dielectric liquid-immersed, self- or forced-cooled, respectively); the third (or the fourth) letter shows the number of windings operating into different circuits if there are more than two such windings (T—three-winding); the fourth (or the fifth) letter H stands for on-load tap changing, if any; the fifth (or the sixth) letter shows lightning-resistant arrangement of windings designated through letter Г (for transformers of old makes).

So, the type designation TДТНГ-20,000/110 is to be decoded as follows: T—three-phase; Д—oil-immersed, forced-oil-cooled, self-oil-circulation; T—three-winding; H—on-load tap changing; Г—with lightning-resistant insulation. The numeric designations show the rated capacity of the transformer and the voltage class of the HV windings.

Available in the USSR are transformers of the following standard capacities: 10, 16, 25, 40, and 63 VA with provision for 10-, 100-, 1000-, and 10,000-fold increase of each of these ratings.

Industrial substations usually incorporate two-winding power transformers TM rated up to 1,000 kVA, oil-immersed, self-cooled. The basic parts of a two-winding power transformer (Fig. 162) are as follows: the magnetic circuit, windings, tank, and the cover. The magnetic circuit of a two-winding transformer (Fig. 163a, b) is a sheet-steel structure built up of 0.35 or 0.5 mm thick laminations, and composed of three vertical legs 1 joined by upper (2) and lower (12)

yokes. The legs carry the transformer windings and the yokes form, together with the legs, a closed magnetic circuit. To reduce eddy currents, the magnetic circuit steel laminations are coated with a thin layer of varnish.

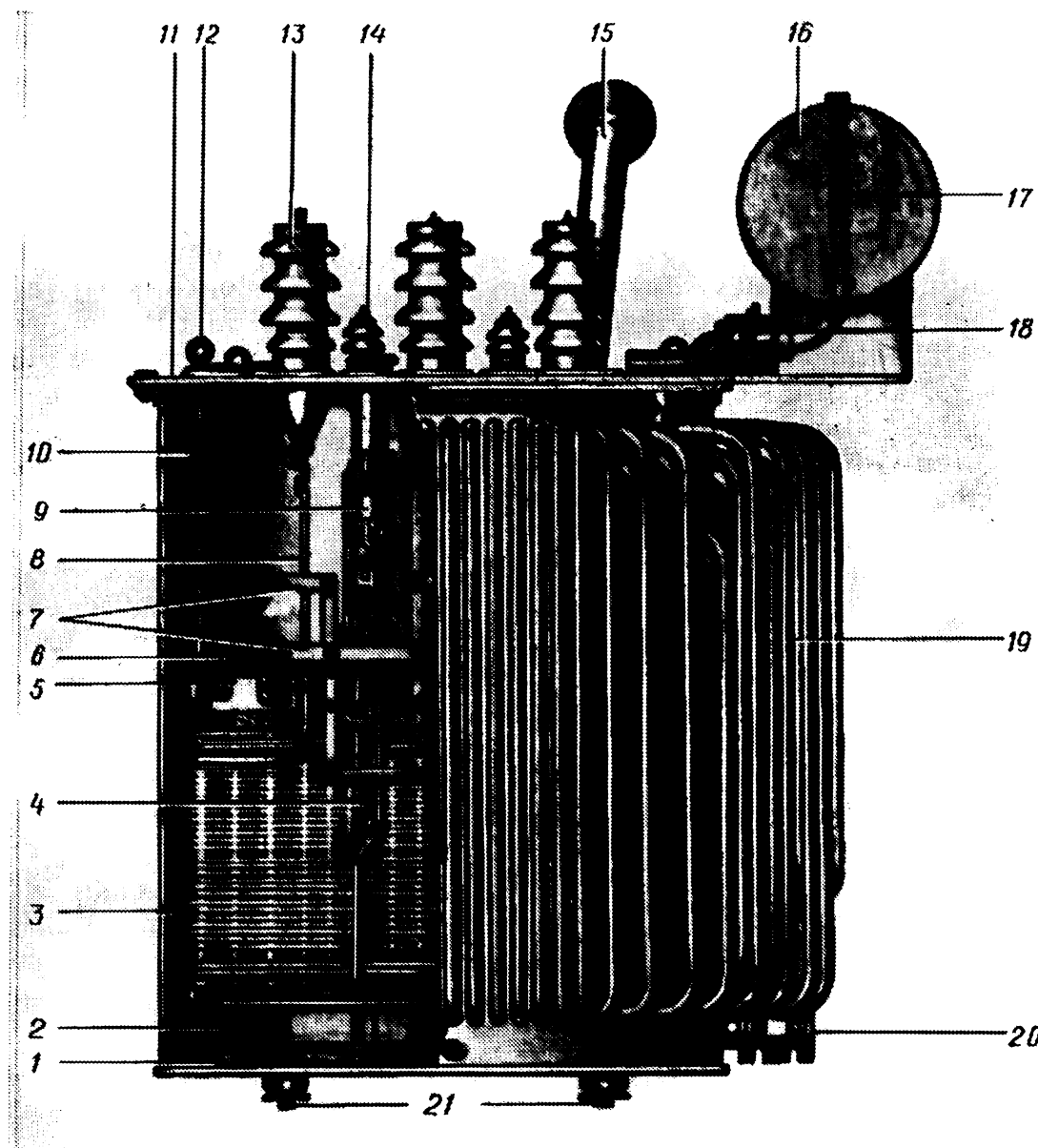


Fig. 162. Oil-immersed three-phase power transformer of 1,000 kVA capacity

1—tank; 2—lower yoke beam; 3—HV winding; 4—voltage-regulation taps to tap changer; 5—upper yoke beam; 6—magnetic circuit; 7—wood strips; 8—HV winding tap; 9—tap changer; 10—lifting stud; 11—tank cover; 12—lifting eye-bolt; 13—HV bushing; 14—LV bushing; 15—safety pipe; 16—conservator; 17—oil-level indicator; 18—gas relay; 19—circulation tubes; 20—oil drain cock; 21—castors

The steel laminations are tightly compressed by means of studs 4 and 8 and yoke channel beams 3. The studs and the yoke beams are insulated from the core to eliminate hot spots on the magnetic circuit and to reduce eddy current loss.

Transformer windings (Fig. 164) are available of many design forms, most popular being barrel and continuous windings made of cotton-covered round or rectangular wires.

A *single-layer barrel winding* (Fig. 164a) is wound with one or more wires in a single layer in a helical manner, with the starting and finishing leads brought out on opposite ends.

A *double-layer winding* (Fig. 164b) is wound in the same manner as a single-layer winding, the only difference being that the wires are arranged in two layers.

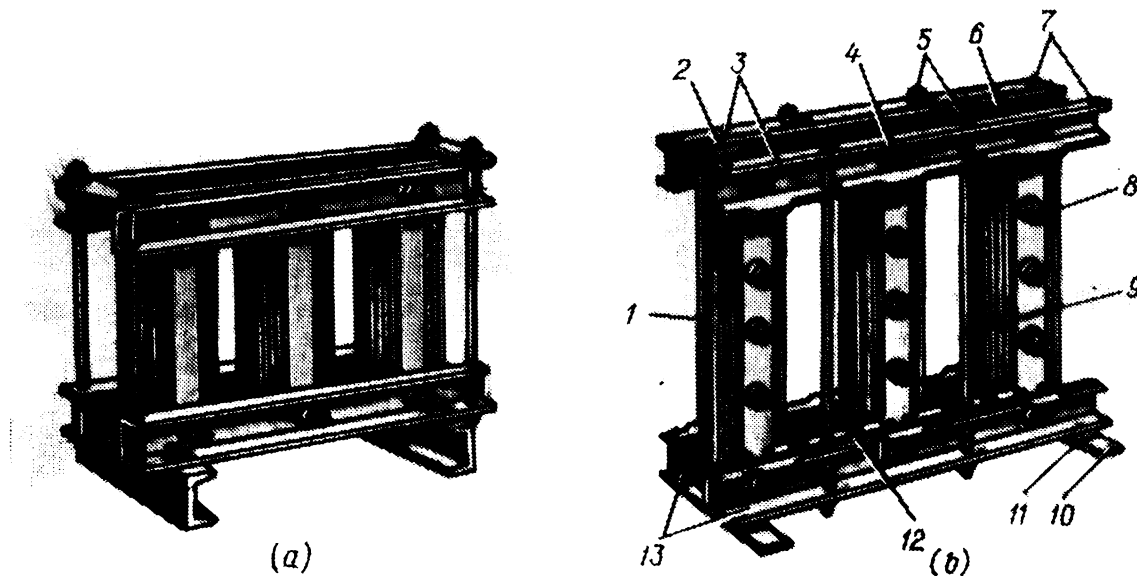


Fig. 163. Core legs of two-winding power transformers

a—100-kVA capacity; b—1,800-kVA capacity; 1—leg; 2, 12—upper and lower yokes; 3, 13—yoke beams of upper and lower yokes; 4, 8—horizontal compressing studs; 5—vertical bracing studs; 6—pressboard gaskets insulating yoke beams from yokes; 7—holes in yoke beams; 9—bakelite tube insulating the vertical stud; 10—steel plate; 11—wooden strip

The single- and double-layer windings may have up to four parallel conductors per turn. They are primarily used on the low-voltage end (up to 660 V) of the transformers of up to 630 kVA capacity.

Transformers of up to 630 kVA capacity for voltage classes of 6 and 10 kV use multilayer barrel windings on the high-voltage side.

A *multilayer barrel winding* (Fig. 164c) is made of round wire wound on a bakelite-treated paper barrel with several sheets of cable paper placed between layers. In the case of a great number of layers, the winding is composed of two coils to ensure better cooling conditions. A vertical duct is formed between the coils by dry wood (beech, oak) strips or several pressboard sheets bonded together.

The multilayer winding is simple to manufacture but its mechanical strength in respect to axial thrusts is insufficient. A greater mechanical strength of these windings is attained by binding them with herringbone or taffeta tape followed by impregnation with glypthalic varnish and baking at a temperature of 80 to 100°C.

Continuous windings (Fig. 164d) are most widely used for power transformers of 1,000 kVA and higher capacities. These windings are built up of series-connected coils wound of flat wires. These windings are referred to as continuous because they are wound continuously, without soldered or other joints. A continuous

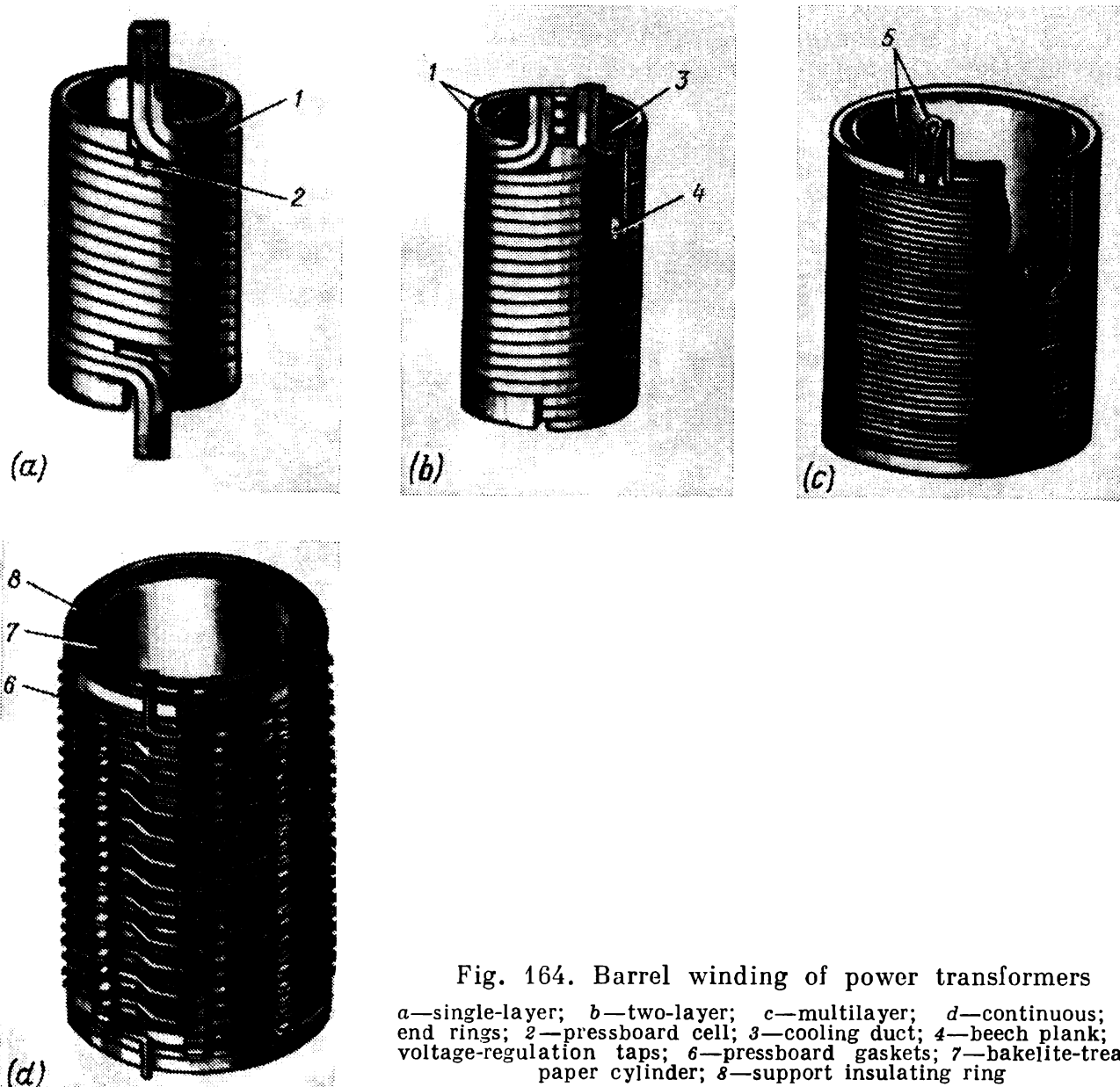


Fig. 164. Barrel winding of power transformers

a—single-layer; *b*—two-layer; *c*—multilayer; *d*—continuous; 1—end rings; 2—pressboard cell; 3—cooling duct; 4—beech plank; 5—voltage-regulation taps; 6—pressboard gaskets; 7—bakelite-treated paper cylinder; 8—support insulating ring

winding is wound on battens placed on a bakelite-treated paper barrel. Spaces formed between the battens function as vertical cooling ducts. Horizontal cooling ducts are made of pressboard sheet stacks strung on oil-treated wood strips.

Continuous windings are noted for higher mechanical strength and used both on high-voltage and low-voltage sides of transformers.

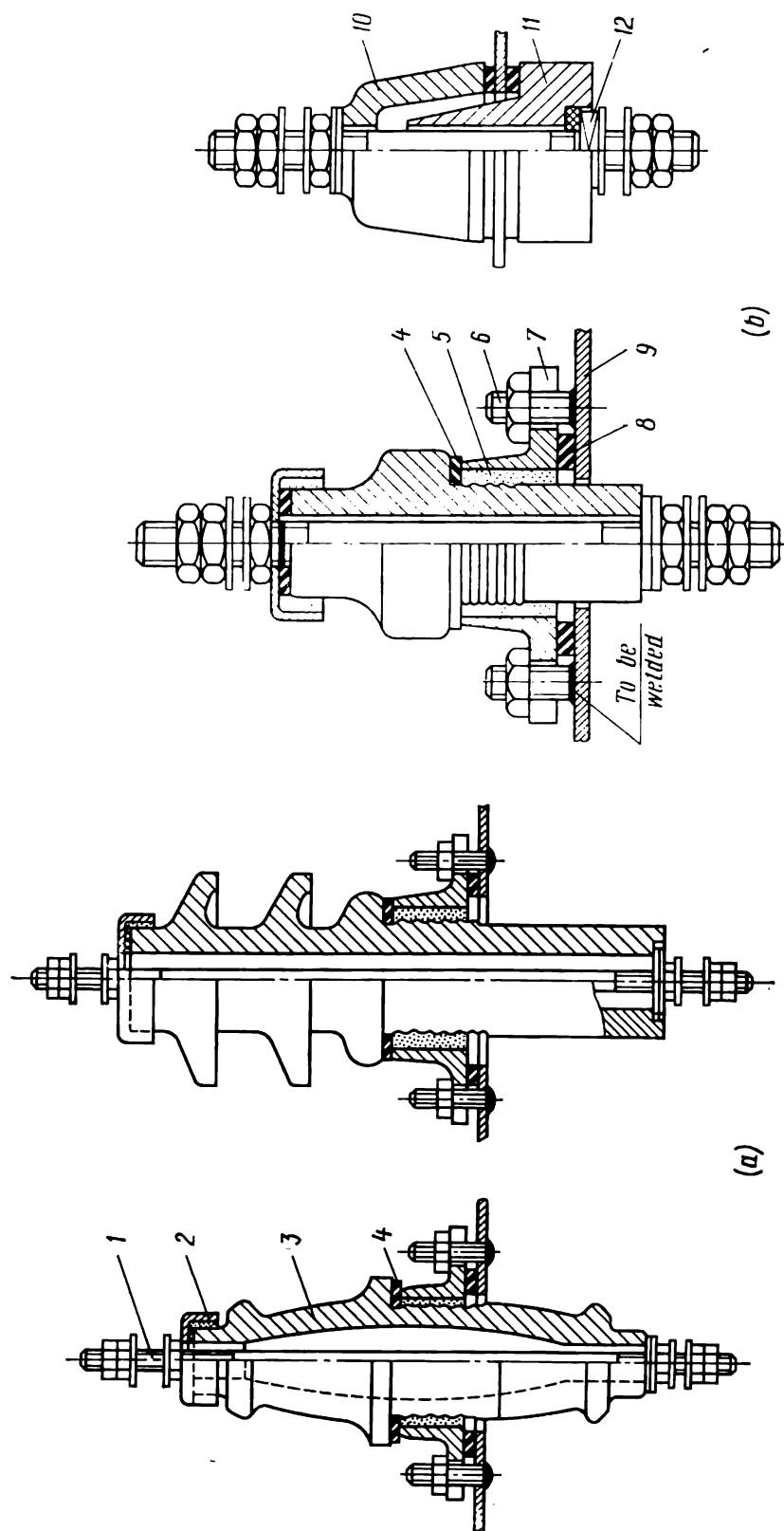


Fig. 165. Indoor and outdoor power transformer bushings
 a — 10-kV; b — 660- and 380-V; 1 — current lead; 2 — steel cap; 3 — porcelain bushing; 4 — rubber washer;
 5 — reinforcing compound; 6 — steel stud; 7 — flange; 8 — gasket; 9 — transformer cover; 10 — external por-
 celain part of composite insulator; 11 — internal porcelain part of insulator; 12 — square steel nut

The magnetic circuit and the coils wound on transformer legs are the active parts of the transformer referred to as the core-and-winding assembly.

The core-and-winding assembly is immersed in oil contained in a metal tank that protects the windings and other parts accommodated within the tank against mechanical damage, and affords a cooling surface required for heat transfer from the transformer.

The transformer tanks are available of different design forms to suit the transformer capacity and operating conditions. The higher the transformer capacity, the greater amount of heat must be dissipated through the tank walls.

The tanks are welded vessels of a rectangular or oval shape. They may be smooth, ribbed, tubular, and with radiators. Smooth-surface tanks are used for low-capacity transformers where the absolute power loss dissipated in the form of heat is comparatively small. Larger transformers of higher than 50 kVA capacity have tanks fitted with round- or oval-section circulating tubes affording better cooling conditions. Still larger transformers are provided with pipe unions and fan-cooled radiators attached to the pipe unions through flanges.

The pipe unions with radiators are fitted with flat radiator valves which make it possible to remove separate radiators whenever required without draining oil from the tank. The tanks are castor-mounted and can be easily handled within the substation room.

The tank is closed with a cover which functions to seal it and to accommodate various instruments and parts, such as a thermometer and a temperature alarm, film cut-out, bushings, tap changer, conservator, gas relay, and an overflow pipe.

The thermometer and the temperature alarm are intended to control the temperature of the upper oil layers within the transformer tank. A standard glass thermometer with a scale range of -20 to $+100^{\circ}\text{C}$ is used for transformers rated up to 1,000 kVA. Larger transformers are furnished with a type TC-100 temperature alarm which functions, along with checking the oil temperature, as a warning device that sends current pulses actuating audio signals or disconnecting devices in the event of oil temperature rising beyond permissible limits.

The film cut-out serves to protect the attending personnel and low-voltage equipment against high voltages with potential transfer from HV to LV windings due to breakdown of insulation between the windings or taps. When LV windings are placed at a high potential, air gaps formed by holes in the mica strip of the cut-out break down and the LV winding is earthed.

The bushings (Fig. 165a, b) of power transformers are reinforced porcelain structures insulating the winding leads brought out of the transformer tank.

The tap changers (Fig. 166a, b) are meant to control the transformer voltage by changing over the HV winding taps, thereby varying the HV-to-LV winding turn ratio (transformation ratio) within ± 5 per cent.

The conservator functions to ensure a constant oil level within the tank and to compensate for oil expansion or contraction due to temperature fluctuations. The conservator also reduces the oil surface contacting with the surrounding air, thereby protecting the oil against moisture and oxidation.

The gas relay (Fig. 167a, b) protects the power transformer against internal damage that may cause hot spots in iron or copper. Very high temperatures decompo-

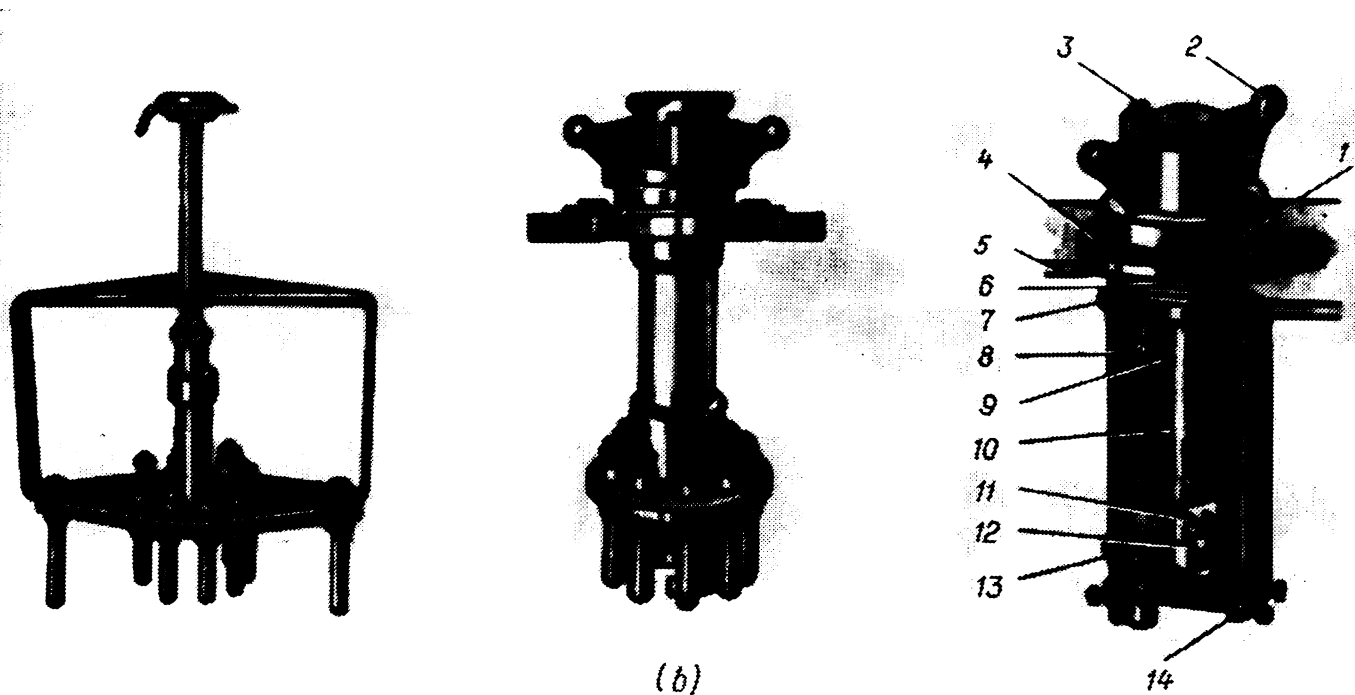
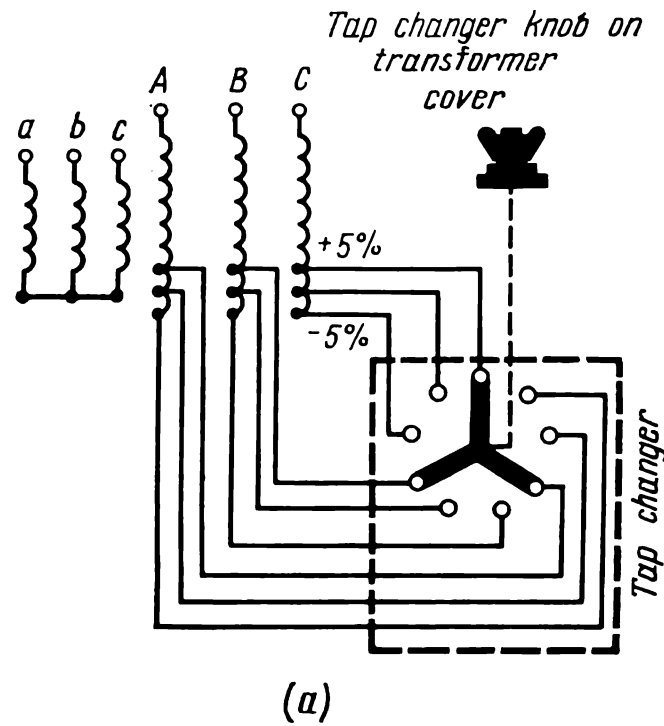


Fig. 166. Transformer tap changers

a—schematic diagram; *b*—general arrangement of tap changers TIICV; 1—tap changer position indicator; 2—operating mechanism cap; 3—locking bolt; 4—flange; 5—transformer cover; 6—rubber seal; 7, 13—cylinder fastening bolts; 8—bakelite-treated paper cylinder; 9—tube fastening bolt; 10—bakelite-treated paper tube; 11—segmental contact; 12—crankshaft; 14—stationary contact with bolt

sing oil, wood, or insulating materials cause liberation of gases which actuate the respective contacts of the gas relay; these contacts complete electric circuits of the transformer warning or circuit-opening devices.

The safety pipe communicates with the tank and serves to discharge gases into the atmosphere in the event of intensive gassing due to fire in iron or any other serious faults. The safety pipe is a steel cylinder whose one end has a flange bolted to the transformer cover, the other end being closed by a glass or foil diaphragm.

In the event of serious internal faults causing an abrupt rise of pressure within the tank and failure of the gas relay, the safety pipe diaphragm breaks by the

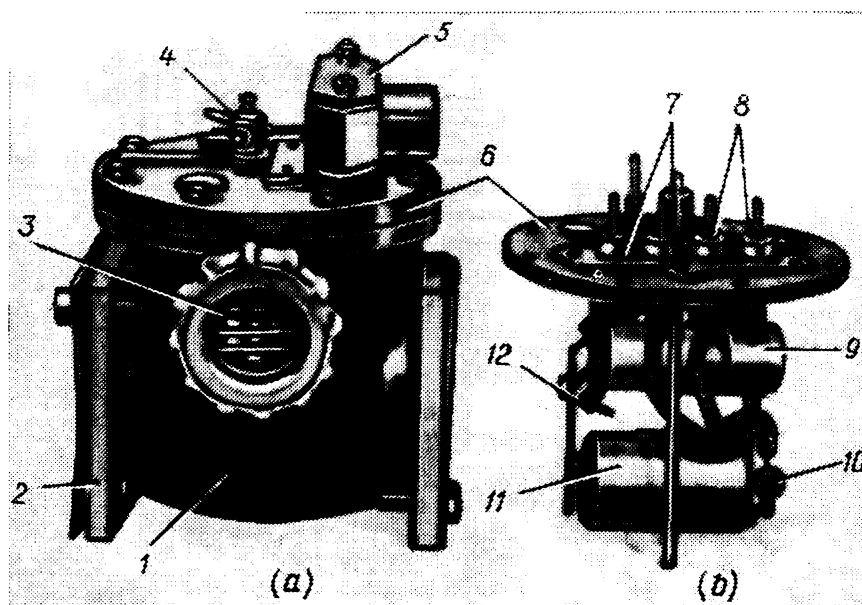


Fig. 167. Gas relay ПГ-22

a—general view; *b*—internal parts; 1—cast-iron case; 2—flange; 3—viewing port; 4—valve; 5—terminal box; 6—cover; 7—signalling contact terminals; 8—opening circuit terminals; 9—signalling circuit float; 10—mercury contact of signalling circuit; 11—opening circuit float; 12—opening circuit mercury contact

gases which escape through it and exhaust into the atmosphere, thereby preventing the exposure of the tank.

A transformer delivered to the installation site shall be thoroughly examined to make sure that bushings, oil-level indicators, and other devices are in good condition, all fastenings are present on the studs of bushings and flanges, the circulation tubes are free from dents, and that there is no oil leakage through welds and seals.

It is not recommended to open the transformers delivered for installation provided they have been stored and shipped under conditions specified by GOST 11677-65 and the pertinent service manual. They may be opened only if faults are suspected within the transformer that can be eliminated on site. Reasons for opening and condition inspection of transformers may be as follows: broken taps or leads of windings, sticking or any other defect in the tap changer, damp windings, etc.

If the transformer is to be opened and subjected to condition inspection at sub-zero temperatures, it must be brought indoors and heated up until its windings and yokes reach a temperature of 20 to 25°C. Most frequently the transformers are heated, with the LV windings shorted out through a bus length, by applying a voltage to the HV winding leads that affords almost the rated current in the windings. The current applied to the winding leads is checked against ammeters, and the heating temperature of the transformer internal parts is controlled by thermometers or metal-framing enclosed thermocouples.

The transformer is to be disassembled in a sequence governed by its mechanical design. To disassemble a transformer having a conservator and bushings mounted on the cover, first oil is drained from the conservator, then bolts fastening the cover to the tank are removed, and the entire winding-and-core assembly lifted from the tank by means of a sling attached to the eye-bolts on the cover. When the bushings are arranged on the tank walls, it is first necessary to drain oil through a drain cock until it is brought to a level 10 to 15 cm below the bushings, whereupon the cover is removed, the winding leads disconnected from the bushings, the bushings are taken out, and the core is lifted from the tank.

When disassembling transformers, measures shall be taken to keep safe all the fastenings, gaskets, and insulating parts.

To facilitate examination and inspection, the core is placed on a solid wooden trestle 40 to 50 cm high.

Condition inspection involving the removal of the core includes the following checks:

(a) the magnetic circuit for tight fitting of parts and laminations; yoke beams for reliable fastening; tightness of nuts on compressing studs, clamping bolts, and other easy-to-get-at fastenings; insulating sleeves, washers and gaskets for missing items and for condition; earthing system for condition;

(b) windings for tight fitting, wedging on core legs, and compression; insulating parts for condition and missing items; windings for damage; soldered and welded joints on leads and dampers for reliability; circuit arrangement for proper setting up;

(c) the tap changer for condition of contacts, reliability of connection of winding taps to them, condition and reliability of operation of the tap changer mechanism, insulation and soldered joints of the winding taps, reliability of fastening of all the tap changer parts.

In addition, a number of tests are carried out to check the following:

(a) insulation resistance of and moisture content in windings (the M-1,101 type 1,000-V, and MC-06 type 2,500-V meggers are used for measuring the insulation resistance of windings for transformers of up to 50 and over 50 kVA capacity, respectively; the moisture content is measured with the ПKB-8 hygrometer);

(b) electric strength of insulation of magnetic circuit bracing bolts by applying a commercial-frequency voltage of 1 kV for 1 minute;

(c) winding resistance that must not go beyond the nameplate data for transformers of higher than 400 kVA capacity by more than 2 per cent.

Faults detected in the course of condition inspections must be eliminated and reduced insulation resistance restored to the normal value by drying out the transformer core.

The transformer core can be dried out by many methods, the most efficient and easy-to-accomplish under mounting conditions being the drying-out in the transformer tank with heating by induction loss in the tank steel.

Before drying, drain oil from the tank, cover it on the outside with glass fabric or asbestos sheets for warming, and wind a magnetizing coil over the covering.

Magnetizing winding data can be obtained from appropriate reference books or found by calculation.

The number of magnetizing winding turns w is found from the equation

$$w = -\frac{AV}{L}$$

where A is proportionality factor varying as a function of specific capacity ΔP ; V is voltage applied to the magnetizing winding, V; L is length of the tank perimeter, m.

Assume that for heating the tank walls the specific capacity ΔP , that is, the capacity per square metre of the tank surface, must be 1 or 2 kW/m², and that for heating the tank bottom 2.5 or 3 kW/m².

Table 43

Proportionality Factor A as Function of Specific Capacity

ΔP	A	ΔP	A
1	1.85	2.0	1.45
1.25	1.70	2.5	1.40
1.50	1.50	3.0	1.34
1.75	1.50		

Taking into account the assumed specific capacity ΔP , find the proportionality factor A (Table 43) and calculate the number of turns w of the magnetizing winding using the above-given equation.

Capacity P required for drying out the transformer core can be found from the equation

$$P = \Delta PLH$$

where H is tank height covered by the magnetizing winding, m.

Select the conductor cross-sectional area from the magnetizing current by calculating the current I with the equation

$$I = \frac{P \cdot 10^3}{V \cos \varphi}$$

where $\cos \varphi$ is power factor assumed to be equal to 0.6.

The magnetizing winding is made of wire covered with heat-resistant insulation (type ПДА double-layer asbestos and the like) and wound so that at least 60 per cent of its turns are arranged at the tank bottom part and spaced 6 to 8 mm apart.

Table 44

**Conditions for Drying Out the Transformer Core
in Its Tank by Induction Loss in the Tank Steel**

Successive stages	Temperature of tank walls, °C	Duration, h
Uniformly raise temperature of the tank walls to 10-20° C	80	4-8
Raise temperature at a rate of 10° C per h	110-120	3-4
Maintain steady state temperature of transformer core and determine the end of the drying procedure	110-120	6-8
Gradually cool down the core	80-60	3-6
Fill the tank with clean and dry oil	50-40	1-2
Cool down the transformer	40-30	Depending on ambient tem- perature

- Notes.** 1. The drying procedure may be terminated if the winding insulation resistance does not practically change within 6 to 8 h at a steady state temperature of 100 to 110° C. The temperature of the core is 15 to 20° C lower than that of the tank. The drying time depends on the transformer capacity, moisture content before drying, drying conditions, and some other factors.
2. In filling the tank with oil, measures must be taken to prevent penetration of dirt and moisture into the oil.
3. The electric strength of oil poured into the tank after drying-out shall not be lower than 25 kV.

In drying, maintain conditions specified by Table 44 and permanently check the temperature of the windings and magnetic circuit by means of thermometers and thermocouples.

After condition inspection and drying, reassemble the transformer proceeding in a sequence reverse to disassembly. While reassembling, clean the transformer tank from remaining oil and mud, clean the oil admission and drain cocks, flush out the safety pipe and the pockets for thermocouples and the silica gel desiccator with clean transformer oil, remove dirt from the surfaces of the windings and magnetic circuit, wipe the glass diaphragm of the safety pipe with clean waste, etc.

When lowering the core into the tank, take care to avoid accidental damage to the windings, taps, and porcelain parts of bushings; do not displace nor crumple the sealing gasket placed between the tank flange and the cover. It is good practice to attach the gasket to the flange in advance with the aid of glyphthalic varnish or to hold it with steel hooks, keeping your hands away from the space between the cover and the tank.

The gas relay is the last to be mounted after it has been tested in a laboratory. The gas relay case, with all floats removed for the time of mounting, must be mounted in the horizontal position with the oil pipe between the conservator and the tank inclined 2 to 4 deg towards the transformer cover. Do not fail to fit glyphthalic-varnish coated asbestos-rubber or sheet-cork gaskets at the joints between the oil pipe and the transformer cover, conservator, and relay case. The viewing glass of the gas relay must be located so as to make it easy to observe the relay inner parts.

Mount the gas relay so that its pointer sharp end points to the conservator and fix the safety pipe so as to provide for convenient observation of the glass diaph-

ragm and exclude oil splashing on nearby equipment under abnormal conditions.

The assembled transformer is delivered to the installation site. When hauled over an inclined surface, the transformer shall not be tilted through an angle exceeding 15 deg. Before wheeling the transformer into the substation room, make sure that nobody stands between the room wall and the transformer.

The body of a transformer furnished with a gas relay must be inclined 1 or 2 deg, towards the conservator by fitting steel strips at least 100 mm long under its castors.

Sensing elements and thermometers mounted on the transformer cover must be sealed with a lead washer or asbestos cord impregnated with bakelite or glyphthalic varnish. Sleeves accommodating mercury and contacting mercury thermometers shall be filled with transformer oil and plugged to prevent moisture penetration.

After the transformer is mounted in position, connect its leads to the switchgear buses, taking care to prevent mechanical thrusts on the leads. Earth the transformer tank.

Give the transformer a trial run to check its components for proper operation. Prior to do this, set its overcurrent protective gear for operation without time delay for the trial period. and connect the gas relay contacts to operate for opening of the oil circuit breaker.

Switch on the transformer across full supply voltage and then listen to the noise produced by the transformer by means of a bakelite tube, 1 m long. A transformer in good condition can be recognized by an even humming noise. In the event of abnormal noise, decrease in the oil level, oil leakage, or any other defects, the transformer must be switched off without delay and thoroughly examined.

A newly installed transformer must be commissioned. For commissioning the following documents must be submitted:

- (a) manufacturer's certificate and reference documents used for installation;
- (b) reports on condition inspection and drying-out of winding-and-core assembly (if this procedure was carried out);
- (c) test reports on the gas relay, relay protective gear and automatic-control devices;
- (d) comprehensive analysis of oil and electric strength test report.

An acceptance report shall be drawn up and signed by the installation contractor official and the user.

9.9. Installation of Current Transformers Rated 6 and 10 kV

The current transformer is an electrical device designed to reduce the primary circuit current to a value suitable for powering measuring instruments, relay protective gear, automatic gear, signalling, and control circuits.

The current transformers are used where heavy currents must be measured by instruments that cannot be connected directly to the circuit under check. Current transformers make it possible to install measuring instruments at a long distance from the circuits under check and in this way to accumulate instruments of different pieces of equipment in one place, such as on a switchboard, a control console, or control board which are under the supervision of attending personnel.

The transformer consists of a closed magnetic circuit in the form of a core built up of electric steel laminations, a primary winding, and a secondary winding. The primary winding 1 (Fig. 168) is connected in series with the circuit under check, and the secondary winding to the current coils of associated instrumentation.

The primary windings of the current transformers are rated at 5 to 10,000 A; the secondary windings are usually rated at 5 A and sometimes at 1 A.

The current transformers are available of five accuracy classes from 0.2 to 10. The current transformers of accuracy class 0.2 are used for precision measurements only. In industrial installations, current transformers of accuracy classes 0.5, 1, and 3 are most frequently used. The accuracy class of any current transformer determines the permissible errors of transformers.

The type designation of a current transformer consists of letters and numerals.

Letter designations, usually from two to five characters, shall be decoded as follows: T — current transformer; П — through-type; O — single-turn or M — multiturn; Л — encapsulated; Ф — porcelain insulation. Letter and numeric designations are arranged in a definite order, in all cases starting from letter T. A self-support-type transformer is designated by the absence of letter П. The numeric designations stand for the rated voltage of the current transformer.

A more detailed type designation includes the transformer model and design form.

There may be a normal model that does not bear any additional designations; a model reinforced in thermal and transient stability, designated through letter Y that is placed between the letter and numeric portions of the main type designation; a model designed for earth-fault protection, designated through letter "3" (in quotation-marks) placed after letter Y and before the numeric portion; a model designed for differential protection, designated through letter Д standing after letter "3" (for example, ТПФУ"3"Д10).

The design form designation is written with a hyphen and includes the accuracy class of the transformer core (0.5, 1, 3) or its application in protective gear (Д, З, Р), the rated primary and secondary currents. If the transformer incorporates more than one core, these data are given by a fraction.

For example, the type ТПОФ10 current transformer of reinforced modification with two cores (Д, accuracy class 0.5, 400 A primary current, and 5 A secondary

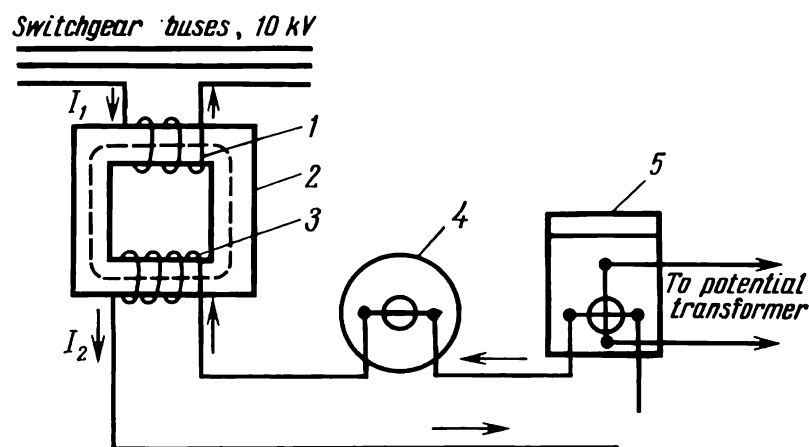


Fig. 168. Connection of current transformer to supply, to measuring instruments and watt-hour meters

1—primary winding; 2—magnetic circuit; 3—secondary winding; 4—ammeter; 5—watt-hour meter

current) is designated ТПОФУ 10-Д/0.5-400/5. This is a detailed or commercial type designation of the current transformer.

The nameplate of each current transformer bears the name of manufacturing plant, transformer type, serial number and year of manufacture, rated voltage (kV)

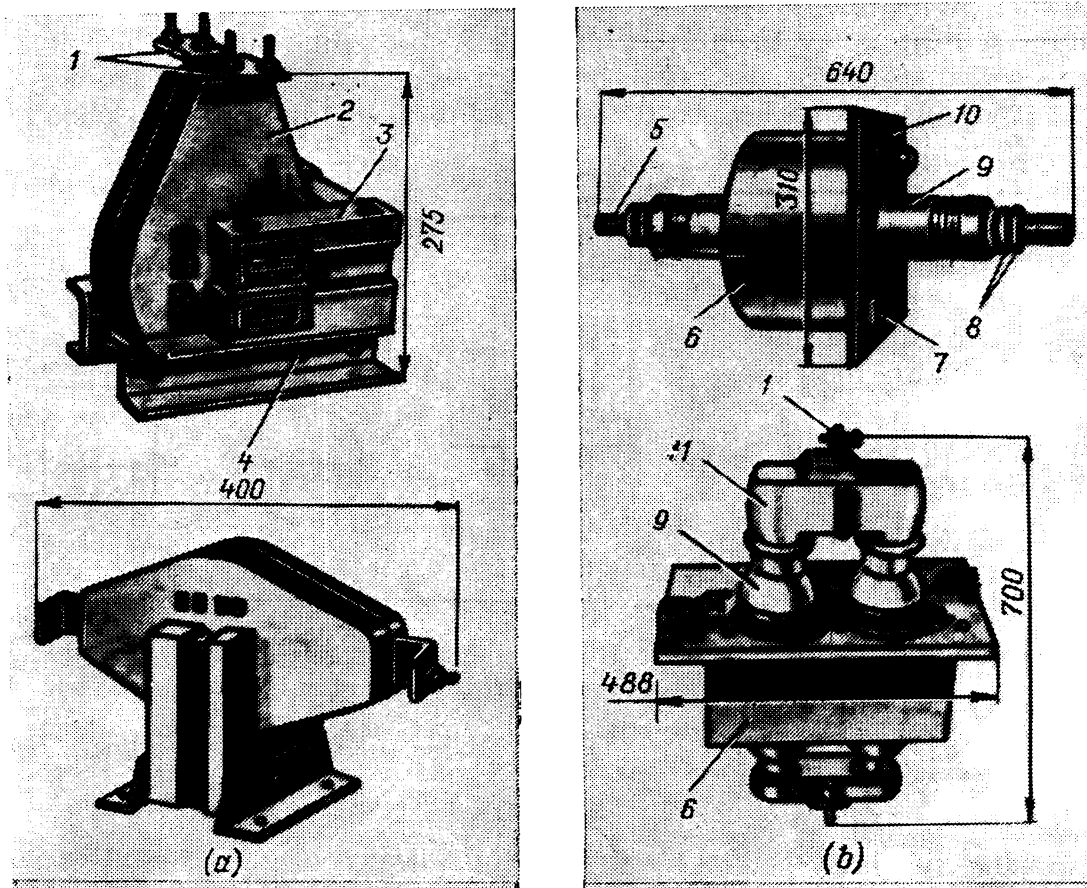


Fig. 169. Current transformers

a — self-support-type ТКЛ and ТИЛ encapsulated transformer; *b* — through-type single-turn (ТПОФ) and multi-turn (ТПФМ) transformers in metal case; 1—lead-in binding posts; 2—epoxy encapsulation; 3—core; 4—earthing bolt; 5—current lead; 6—case; 7—secondary winding terminal box; 8—nuts for connecting switchgear buses; 9—insulators; 10—cover; 11—end box

rated frequency (Hz), rated transformation ratio (rated primary-to-secondary current ratio), accuracy class or relay protection model (Д, З, Р) for each core and burden at which the specified accuracy class is guaranteed, 10-per cent ratio and a burden specified by the nameplate, thermal stability ratio or transient stability.

The current transformers may be made single-turn or multi-turn, self-support-type (Fig. 169*a*) or through-type (Fig. 169*b*).

Current transformers delivered to the installation site shall be thoroughly examined; their insulating parts and contact surfaces are checked for condition and fastenings are checked for missing items and for damage. Encapsulated ТКЛ and ТИЛ transformers and metal cases of ТПОФ and ТПФМ transformers shall be

examined for appearance, and porcelain insulators inspected for any defects. It is also necessary to make sure that the seals are not broken.

The type ТПОФ and ТПФМ current transformers shall be checked for reliable electric contact between the metal case and the metallized surface of insulators.

Metallized surfaces are obtained by spraying graphite or metal on a small area of insulators with the aid of an electric spray gun. The conducting coat thus obtained is meant to afford a uniform field strength between separate parts of the current transformer.

If serious defects that cannot be remedied on site are revealed (such as damaged insulators, earth fault of insulation, deep dents on the case, open circuit in the secondary circuit, etc.), the current transformer shall be rejected. Current transformers with broken or missing seals may be accepted for installation if they have passed appropriate laboratory tests in the presence of an official of the National Bureau of Standards, Measures, and Measuring Instruments.

Minor defects revealed during check-ups shall be eliminated before installing the transformers.

In the event of no contact between the conducting coat on the insulator surface and the transformer case, the sprayed coat on the insulator must be restored. In the type ТПОФ current transformers, the conducting coat is to be applied to the non-glazed surface in the middle of the insulator portion accommodated within the case and contacting the latter.

Prior to mounting the current transformer, its primary-to-earth insulation resistance shall be checked with a 2.5-kV megger. The transformer may be accepted for installation if this insulation resistance is not lower than 100 MΩ as measured at a temperature of 25°C. The secondary winding insulation resistance, as measured with a 1-kV megger, shall not be lower than 6 MΩ. If the results of check are inadequate, the transformer windings shall be dried out by passing through the windings electric current as high as 100 or 110 per cent of the rated value.

Pending installation, the transformer secondary windings must be reliably shorted out. This is necessary to avoid damage to their insulation and to exclude danger of electric shock for electricians working with secondary circuits in the event primary circuits start passing current by accident*. This may happen in the course of installation, for example, when power is supplied to electric welding installations through switchgear buses, or when trial feeding of newly installed switchgear buses is not co-ordinated.

Installation of a power transformer is reduced to its mounting on a supporting structure, connection of the primary leads to the switchgear buses and the leads of secondary switching circuits to the secondary winding terminals, and earthing of the transformer metal case or base.

The self-support-type current transformers are usually mounted horizontally, and the through-type transformers either horizontally or vertically on rigid welded angle steel structures measuring 50 × 50 × 5 mm. The mounting procedures are illustrated by Fig. 170a, b. In the action, clearances specified by the project must

* When the transformer primary carries current, very heavy currents are induced in the open secondary winding, causing inadmissible heating of the magnetic circuit, insulation breakdown, or accident.

be maintained. The minimum clearance between the current-carrying parts of different phases of 10-kV transformers and between these parts and the closest earthed structures or building components shall be 125 mm.

The transformer flanges must be tightly fitted at all their four corners to the supporting structure surface. This can be attained by means of steel shims.

Switchgear buses must be connected to the primary leads with particular care so that the joint, when continuously carrying working currents, should not heat above the temperature of the entire bus system. The connection must be capable of withstanding mechanical and thermal effects of short-circuit current. This is

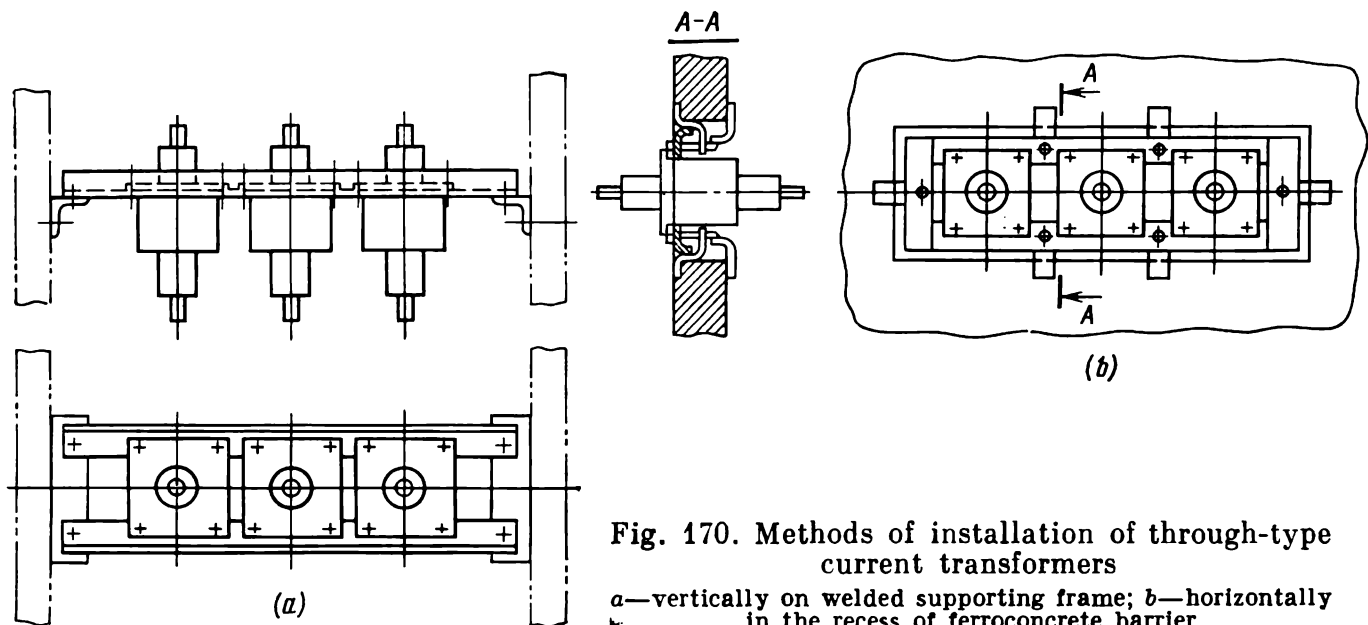


Fig. 170. Methods of installation of through-type current transformers

a—vertically on welded supporting frame; *b*—horizontally in the recess of ferroconcrete barrier

achieved by thorough treatment of contacting surfaces of buses and transformer leads being interconnected, use of spring or oversize washers at the nuts and heads of fastening bolts, tightening of contact bolts with adequate force.

When connecting instruments or relays to the transformer secondary terminals, polarity of windings shall be observed.

The transformer shall be earthed by means of an earthing conductor or busbar connected with one end to a special earthing device or to a substation earthing system, and with the other end to the current transformer.

The end of the conductor or busbar to be connected to the transformer is attached to the earthing bolt labelled "3" and fixed through the latter to the transformer flange (angle plate, base). Prior to being connected to the transformer, the contacting surfaces on the conductor or busbar and on the transformer must be cleaned off and coated with petroleum jelly.

9.10. Installation of Potential Transformers

A potential transformer is designed to supply with power voltage coils of measuring instruments, relays, signalling, control, and automatic-control circuits.

The potential transformer is similar in construction and principle of operation

to a standard power transformer, the only difference being that it has a low capacity. The maximum capacity of the type HOM-10 potential transformer, for example, is 720 VA.

Different types of potential transformers are distinguished by the number of phases (three-phase and single-phase), number of windings (two-winding and three-winding), accuracy class (potential transformers used for industrial purposes on power systems, substations, switchgear, etc. have an accuracy class of 1 and 3; those employed for power meters are of accuracy class 0.5), by the cooling system (oil-immersed and dry-type), and installation conditions (outdoor or indoor).

The *rated voltage* of the potential transformer is the working voltage across its primary (HV).

The ratio of rated voltages across the HV and LV windings is the *transformation ratio* of the potential transformer.

The Soviet-made potential transformers are available with the HV side rated at all the standard voltages from 0.38 to 500 kV.

Single-phase potential transformers whose HV winding lead is earthed for the working period are rated at corresponding voltages to neutral, such as $6 : \sqrt{3}$ kV, $10 : \sqrt{3}$ kV, etc. Voltages across the secondary LV side of the transformer are 100, $100 : 3$, and $100 : \sqrt{3}$ V.

The *rated capacity* of the potential transformer depends on its accuracy class. It is the output capacity indicated on the transformer nameplate that ensures the desired accuracy at the rated primary voltage.

The primary HV leads of three-phase potential transformers are labelled A, B, C, and the respective secondary leads a, b, c and 0. The leads of single-phase transformers are labelled A-X and a-x, respectively.

The type designation of potential transformers consists of letters and numerals denoting the following: H — potential transformer; O — single-phase; M — oil-immersed; C — dry-type; K — encapsulated (in the type designation HOCK) or with compensating winding (in the type designation HTMK); H — five-legged (for the connection of earth-fault detectors); T — three-phase (in the type designation HTMI); numerals that follow letters indicate the rated voltage of the HV winding.

Most widely used for 10-kV substation switchgear are potential transformers, types HOM-10 (Fig. 171a), HTMK-10 (Fig. 171b), or HTMI-10.

The 10-kV potential transformers of other types do not appreciably differ from those mentioned above as far as their mechanical design, principle of operation, and connection to power supply are concerned.

The main criterion in the selection of the potential transformer type, specifications, and circuit arrangement for the connection to power supply is the purpose that the transformer must serve.

A single-phase two-winding potential transformer is connected to voltage between lines of a three-phase network using a circuit arrangement illustrated by Fig. 172a. One of the secondary leads in this connection is earthed to afford safety in maintenance.

Two single-phase potential transformers are connected to three-phase supply in open delta (Fig. 172*b*) to feed voltmeters, wattmeters, and watt-hour meters.

For earth-fault detectors, three single-phase potential transformers are connected in star (Fig. 172*c*).

A three-legged three-phase potential transformer of the HTMK type is connected to three-phase supply by using a circuit arrangement of Fig. 172*d*. The transformer primary is connected in star, and the secondary in star with the neutral wire brought out. The HTMK transformer is used in three-phase insulated-neutral systems

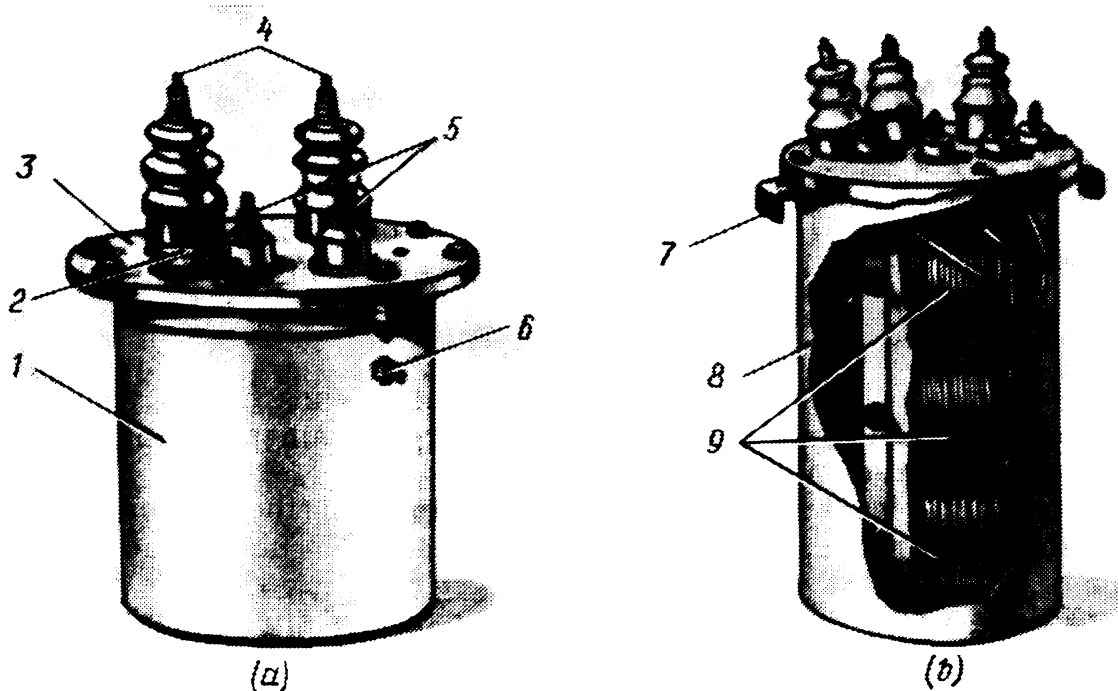


Fig. 171. Potential transformers

a—single-phase, type HOM-10; *b*—three-legged three-phase, type HTMK-10; 1—tank; 2—oil filler plug; 3—cover; 4—primary (HV) leads; 5—secondary (LV) leads; 6—earthing bolt; 7—lifting eyebolt; 8—magnetic circuit; 9—LV windings

to supply with power measuring instruments and protective gear elements only. It cannot be employed to feed an earth fault detector and earth-fault protective devices because earthing of the transformer primary with one of the supply leads shorted through earth will induce opposing fluxes through the core legs, which may cause excessive heating of the windings.

If potential transformers are meant for use in three-phase 10-kV lines to feed measuring instruments and earth-fault detectors at a time, the type HTMK-10 is most suitable. The circuit arrangement for the connection of this transformer is illustrated by Fig. 172*e*.

The HTMK potential transformer is furnished with three main and two auxiliary core legs. The main legs carry one primary and two secondary windings (main and auxiliary); the auxiliary legs are not wound and function as shunts. The pri-

mary and the main secondary windings are connected in star with the neutral brought out; the auxiliary secondary winding is connected in open delta. The primary neutral is earthed to discharge static charges induced in the line. The main secondary winding is connected to the supply circuits of measuring instruments, and the auxiliary secondary winding to the earth fault detector circuit, earth-fault relay, and signalling devices.

In the event of earth fault in one of the line phases, the magnetic flux of the remaining two phases closes through the extreme core legs, with the result that a

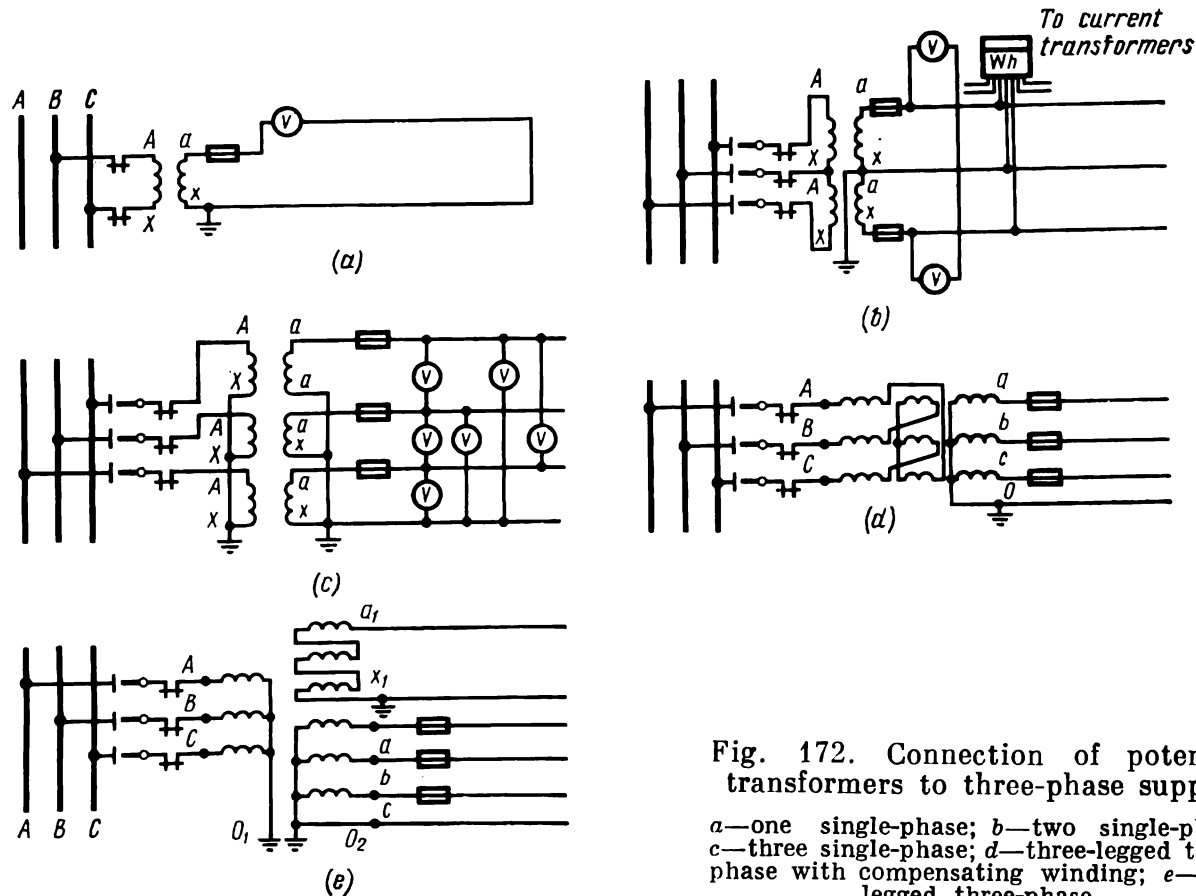


Fig. 172. Connection of potential transformers to three-phase supply
a—one single-phase; *b*—two single-phase;
c—three single-phase; *d*—three-legged three-phase with compensating winding; *e*—five-legged three-phase

certain voltage is built up across the terminals of the auxiliary winding. In the action, the relay connected to this winding will start passing current and operate.

Potential transformers delivered to the installation site shall be examined and, if necessary, subjected to condition inspection involving the removal of the winding-and-core assembly and drying-out of the windings; these operations are similar to those described for power transformers.

Potential transformers are installed in a separate switchgear chamber, cubicle, or section. The primary circuit of the potential transformer must incorporate fuses and current-limiting reactors so that a faulty potential transformer might not cause failure of the entire electrical installation. The potential transformers are usually controlled by isolators. Fuses inserted in the secondary circuit function to prevent short circuits in this circuit.

Potential transformers are mounted on a metal bedframe, 200 to 250 mm high, attached to the cubicle or chamber floor, on angle plates welded to the embedded parts of the chamber or to the cubicle frame (in unit transformer substations or metal-clad switchgear), on supporting structures attached by means of screws or dowels driven in with the aid of a gun, etc. When transformers are mounted on angle steel plates, the front supporting angle plate must be set with its flanged edge down so as to facilitate the transformer drawing out for inspections and replacements. Special lifting yokes are provided in the transformer case or cover for its handling. The oil-drain plug and the oil-level indicator must face the maintenance passageway.

To ensure better cooling conditions for potential transformers installed in enclosed switchgear cubicles, their casings must be spaced at least 100 mm from the walls.

The switchgear buses connected to the transformer winding leads must not cause excessive thrusts on the leads.

With three-phase transformers, the lead labelled A is connected to a yellow bus (phase A), that labelled B to the green bus, and the lead labelled C to the red bus. With single-phase transformers, lead A may be connected to any phase. If three single-phase transformers are installed, all the leads labelled x are connected through a common bus into a neutral point and earthed.

The case of each potential transformer is connected to the earthing system through a separate steel bus having a cross-sectional area of minimum 48 mm²; the transformer secondary windings must also be earthed unless specified otherwise by the project.

After the transformer is fully mounted and wired, the electric strength of its secondary winding insulation shall be tested by applying a commercial-frequency voltage of 1 kV for 1 minute, and an open-circuit current at the rated voltage of the secondary winding (the open-circuit current is not specified and shall be compared with factory data from which it shall not differ by more than 10 per cent).

Prior to placing in operation an oil-immersed potential transformer, the sealing washer must be removed from under the filler (top) plug to afford easy air exchange (vent plug operation).

In order to prevent accidents resulting from the voltage set up across the transformer leads at the moment of unwanted contact with bare parts of temporary wiring or wires of welding sets, the primary and secondary windings of the potential transformer must be reliably shorted out across the terminals throughout the entire period of installation.

Review Questions

1. What is the purpose of isolators and how are they mounted?
2. Describe the mechanical design and construction of power-isolating switches and methods of adjustment of the blades travel into stationary contacts.
3. Describe the general arrangement of the BMII-10 oil circuit breaker and basic operations involved in its installation.
4. Describe the general arrangement of the IIIM-10 operating mechanism and requirements for its installation.

5. Describe the general arrangement, principle of operation, and methods of installation of fuses ПР and ПРТ.
6. What is the purpose of the current-limiting reactor and how is it installed? What forms of installation of the reactor sections do you know?
7. What are the basic parts of a power transformer, how are they constructed and what is their purpose?
8. What methods of drying-out of power transformer insulation do you know? What maximum heating temperatures may be admitted in drying? How are drying conditions checked?
9. What is the purpose of a current transformer, how is it constructed and what shall be done to mount it?
10. What is the purpose of a potential transformer and how is it mounted?
11. What safety precautions shall be observed when mounting substation equipment?

Installation of Earthing Systems

10.1. General

Earthing systems are meant to protect attending personnel against electric shock upon the appearance of voltage on pieces of electrical equipment that are normally dead and to ensure normal operation of these pieces of equipment.

An earthing system is a combination of an earthing device and earth conductors.

An earthing device is a metal conductor or a group of metal conductors driven into the earth.

Earth conductors are metal conductors interconnecting the electrical equipment parts being earthed and the earthing device.

Earthing of any part is an intentional electrical connection of this part to earth.

The resistance of an earthing system is the total resistance of the earthing device to earth and the earth conductors.

Voltage to earth is the voltage between the equipment body that is earthed and the points of earth beyond the region of earth currents but not closer than 20 m.

Earth fault is an accidental electrical connection of live parts of electrical equipment to earth or to structural elements not insulated from earth.

Earth-fault current is the current flowing through the earth at the point of earth fault.

Solidly earthed neutral is the neutral of a generator or transformer connected to an earthing device directly or through a low resistance (current transformer, etc.).

Insulated neutral is a neutral that is not connected to an earthing system or earthed through high-resistance devices, such as potential transformers, etc. that compensate for the line capacitance current.

In the event of insulation breakdown in an electrical device (magnetic starter, power transformer, high-voltage circuit breaker, etc.), an electric circuit may be completed through the live part with faulty insulation that will carry the earth-fault current. The earth-fault current (I_e) depends on the current system of the line, its power, length, and the fault circuit resistance.

The earth-fault current will flow through the earthed metal body of the equipment to the earthing system and through the latter to earth wherein it will spread uniformly (if the soil is uniform); as it flows farther from the earthing system, its density reduces.

Since the current density at the earthing device is at its maximum, the voltage drop across the earth at this point is also at its maximum. Farther from the earthing device the voltage decreases, and at a distance of approximately 15 or 20 m it becomes negligible and may be assumed zero.

Therefore, the zero potential points* are assumed to be earth surfaces at a distance of not over 20 m from the earthing device.

The earthing device resistance to earth (R_e)** is defined as the ratio of voltage to earth across the earthing device to current flowing through the earthing device to earth, that is,

$$R_e = \frac{V_e}{I_e}$$

where V_e is voltage to earth across the earthing device at zero potential point; I_e is earth-fault current.

A *protective earthing system* is an earthing system designed to afford electric safety of equipment where normally dead metal parts are earthed through earthing

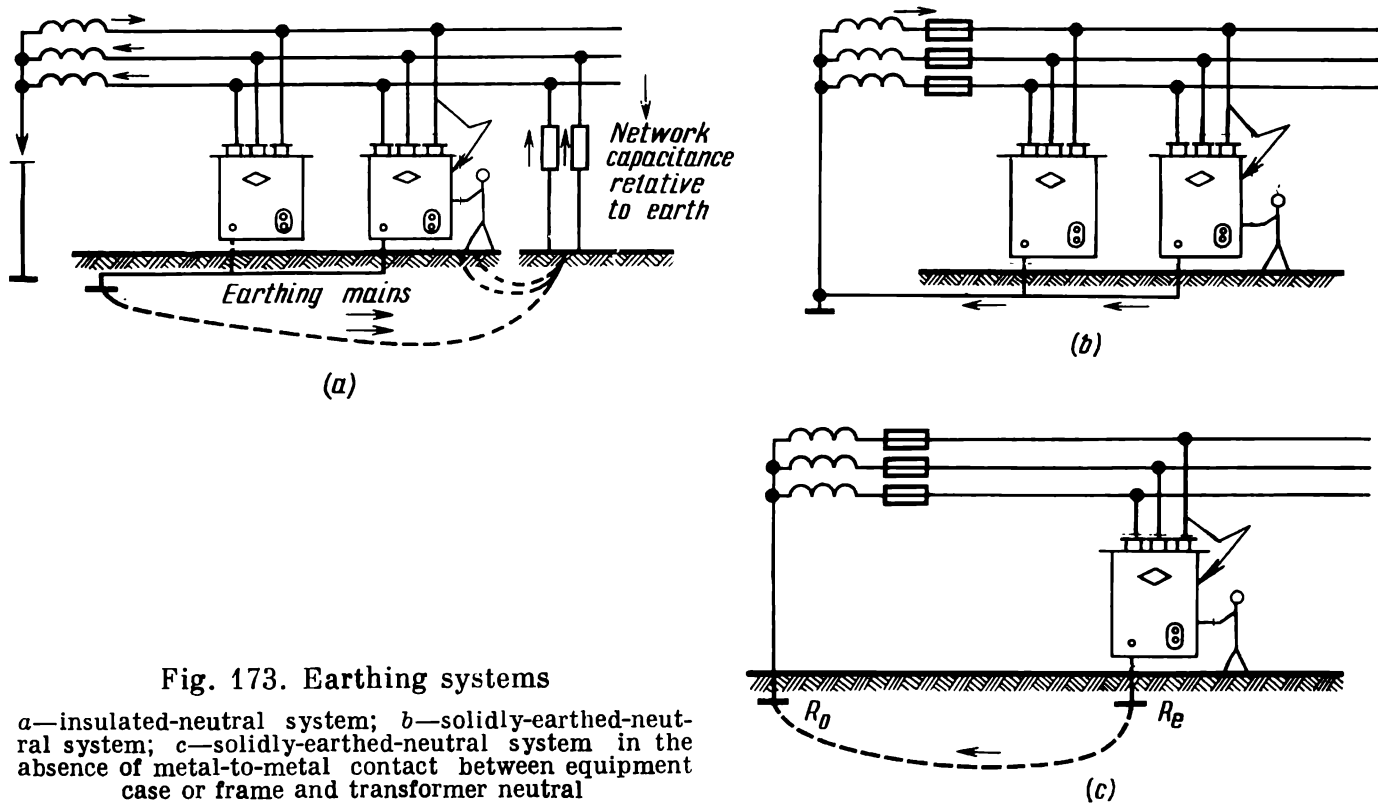


Fig. 173. Earthing systems

a—insulated-neutral system; b—solidly-earthed-neutral system; c—solidly-earthed-neutral system in the absence of metal-to-metal contact between equipment case or frame and transformer neutral

devices and conductors. Such a system may be considered as protective earthing system only if it is made in full compliance with appropriate standards or specifications.

Electrical installations rated up to 1,000 V may incorporate transformers or generators with a solidly earthed or insulated neutral.

For insulated-neutral installations (Fig. 173a) use is made of protective earthing systems which connect the metal parts of the earthed electrical equipment or installation to the line in the event of breakdown of their insulation. When you

* Zero potential points are points placed practically at earth potential.

** The term "earthing device resistance to earth" and the term "spreading resistance" are often replaced by the term "earthing device resistance".

happen to be in contact with them, the current will flow through your body and through the earthing system. A greater portion of current will flow through an earthing system having a lower resistance.

The resistance of an earthing system made in compliance with appropriate standards and specifications is hundreds of times lower than that of human body, and therefore the bulk of earth-fault current will pass to earth and only a negligible current will pass through your body.

In solidly earthed neutral installations rated 380/220, and 220/127 V, use is made of a protective earthing system in which the earth conductors and the electrical equipment components to be earthed are intentionally connected to the earthed neutral of the generator or transformer via conductors (Fig. 173b). With this arrangement, each connection of a current-carrying part to earth causes a short circuit that is cleared by the closest fuse or circuit breaker. Such a system is referred to as a solidly earthed neutral system.

The solidly earthed neutral system is used in electrical installations with solidly earthed neutral rated up to 1,000 V because standard earthing systems cannot afford the desired safety under these conditions.

In the absence of metal contact with the transformer neutral in the solidly earthed neutral system (Fig. 173c), the earth fault will cause a flow of current that will not always be sufficient for a circuit breaker to open or for a fuse to blow out.

A common earthing system is used for different electrical installations rated at different voltages. The common earthing system must meet the requirements of the separate earthing system that must have the lowest resistance. So, when using a common earthing system for two electrical installations and one of them must have an earth resistance of not over $4\ \Omega$ and the other not over $10\ \Omega$, the common earthing system must have a resistance of not over $4\ \Omega$.

All the electrical installations rated 500 V and higher must be earthed by all means. For voltages of higher than 36 V a.c. and over 110 V d.c., protective earthing systems are used with outdoor electrical installations and those mounted in hazard and extra hazard locations.

At rated voltages below 36 V a.c. and below 110 V d.c., electrical installations do not require protective earthing.

The following parts are to be earthed: frames of electrical machines, cases of transformers, circuit-opening devices, lighting fixtures, and starting gear; operating mechanisms of isolators and high-voltage circuit breakers; secondary windings of instrument transformers; frames of switchboards, control boards, panelboards and boxes; metal structures of switchgear installations; metal cable structures, metal bodies of cable boxes; metal sheaths and armours of control and power cables, metal sheaths of wires; steel pipes and conduits of wiring systems; overhead line ferroconcrete support accessories.

The following pieces of equipment are not subject to earthing: accessories of suspension insulators and pins of support insulators; brackets and lighting fittings mounted on wood-pole supports of power transmission lines and on wooden structures of outdoor substations (unless lightning protection requires it); pieces of equipment mounted on earthed metal structures (when this is the case, the surfaces of equipment contacting the earthed metal structure must be thoroughly cleaned off to

ensure reliable electric contact between them); relays and miscellaneous circuit-opening devices mounted on switchboards, panelboards, in boxes, and on the walls of cubicles of switchgear installations; detachable and opening parts of earthed metal frames and cubicles of switchgear installations, fenders, cabinets, doors, etc.

10.2. Installation of Earthing Devices

Earthing devices are most important parts of earthing systems. That is why they may be installed only with reference to an approved and coordinated plan. Both natural and artificial earthing devices may be employed. Natural earthing devices are metal structures already mounted in the ground that are suitable for connection to earth. Natural earthing devices shall be favoured as they save metal and labour otherwise consumed for earthwork and installation.

Employed as natural earthing devices are water pipes and miscellaneous metal pipes buried in the ground, casing pipes of artesian wells, metal structures buried in the ground, earthed fittings of ferroconcrete buildings and constructions, metal piles of hydropower structures, lead sheaths of cables buried in the ground.

If cable sheaths are used as the only earthing devices, they must be taken into account in the earthing system design provided not less than two cables are available.

Natural earthing devices must be connected to the overall earthing system of the electrical installation through at least two conductors attached to the earthing device at different points.

Pipes of combustible liquids, combustible and explosive gases, pipes covered with anticorrosive compounds shall never be used as natural earthing devices.

In the absence of natural earthing devices in close proximity to the electrical equipment, artificial ones shall be made. Artificial earthing devices are special metal pieces driven into the ground and meant for the connection of earth conductors to them.

Artificial devices can be made of steel pipes, angle plates, metal rods, steel strips and the like placed in the ground either horizontally or vertically.

Minimum dimensions of steel earthing devices and earth conductors are specified by Table 45.

Table 45

Minimum Dimensions of Steel Earthing Devices and Earth Conductors

Dimensions	Indoors	Outdoors	In ground
Diameter of round conductors, mm	5	6	6
Thickness of angle steel racks, mm	2	2.5	4
Cross-sectional area of rectangular conductors, mm ²	24	48	48
Thickness of rectangular conductors, mm	3	4	4
Wall thickness of steel pipes, mm	2.5	2.5	3.5
Wall thickness of thin-walled steel pipes, mm	1.5	Shall not be used	

Zinc- or copper-plated earthing devices shall be employed where they may be attacked by corrosion in the ground.

Earthing devices and earth conductors buried in the ground must not be painted.

Earthing devices are most frequently made of pieces of pipes or angle steel, 2.5 or 3 m long. Earthing devices of such a length are less affected by frozen ground. Angle steel shall be preferred as spreading resistance of an angle-steel earthing device is lower than that of a pipe of the same mass.

The earthing device electrodes shall be arranged so that their upper ends are 0.5 to 0.7 m below the ground line. This will make it possible to reduce the spreading resistance of earthing devices and to make this resistance less dependent on ambient temperature fluctuations.

For installing earthing devices, first dig a trench, 0.7 m deep and 0.5 to 0.6 m wide at the bottom, then drive in the earthing devices either manually or by means of power-operated tools.

Electric drills or special tools are most suitable for driving in round steel earthing stakes. When using an electric drill, first prepare a steel stake, dia 15 to 18 mm, sharpen it on one end, and then fit on the stake (50 mm off the end and weld in position a radially cut washer developed into a spiral to make an auger-like piece.

Washers must be cut and welded to the stakes in advance in special workshops equipped with welding sets. For driving the earthing stake into the ground, make use of an electric drill fitted with a reduction unit (Fig. 174a). To drive in the

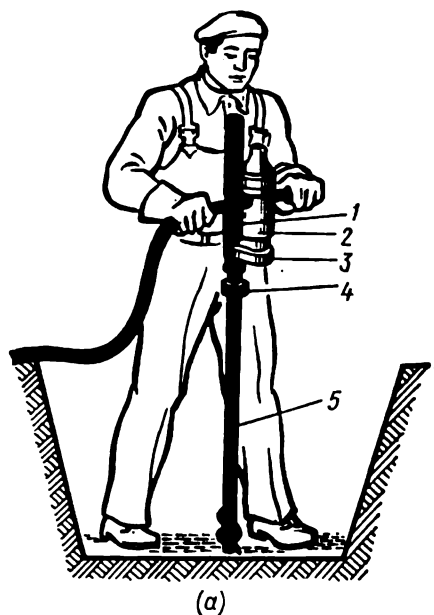


Fig. 174a. Driving an earthing stake into the ground by means of an electric drill.

1—spindle; 2—electric drill; 3—reduction unit; 4—three-cam clutch; 5—earthing stake

stake by this method, insert it into a hollow spindle and clamp in a three-cam clutch at a distance of 1.5 m from the end to be buried in the ground. As the drill is switched on, the stake starts rotating. As soon as a certain portion of the stake is buried in the ground, switch off the drill, set the clutch cams apart, raise the whole mechanism along the stake to a height of 1.5 m above the ground level and clamp the stake in the clutch cams again. Repeat this operation until the stake is driven in to the desired depth. In cold seasons, especially when the ground is heavily frozen, the drill power may appear to be insufficient for driving the stake into the ground. When this happens, preheat the ground or make a hole, 0.5 to 0.8 m deep, with a twist drill of an appropriate diameter, then drive in the earthing stake.

If earthing steel stakes are to be driven into frozen or hard earth or through a depth exceeding 3 m, a power-operated earthing bore shall be used for the purpose. This bore greatly facilitates the work. The type 3Э-1 earthing bore (Fig. 174b) consists of a hollow spindle carrying a three-cam clutch and a welded frame with wheels which are mounted on a collapsible tubular axle. When placed over the trench, the axle can be expanded to the desired length. The spindle is driven by

a type AOJI-2-21-4 motor 7 of 1.7 kW output, via a pair of straight-spur gears. The spinner and the drive move along vertical rods 6 of the frame. The downward working stroke takes place by gravity under the action of the bore and self-lifting gear mass. The upward idle stroke is afforded by a winch driven from the rotating spindle via a bevel pair. When driven into the ground, the pointed-end electrode with a welded borer is brought into the spindle, whereupon the motor is switched on and the bore moves to the upper position. Then the electrode is clamped in the chuck, the motor is switched on again, and the electrode is driven into the ground through the full stroke of the moving part. Then the motor is switched off, the electrode is released from the chuck and the process is resumed as many times as is required to drive the electrode through the desired depth. The earthing bore is convenient in operation, simple in construction, and is noted for high capacity. So, an electrode as long as 5 m can be driven into frozen ground within 12 min, and into thawed ground within 4 min. The overall dimensions of the spinning tool are as follows: width (wheel included) — 800 to 1,200 mm; length — 900 mm; height—2,400 mm; its mass is 80 kg.

Angle steel electrodes can be driven into frozen or hard ground by means of a contactless single-phase percussive drive mechanism. The master and final element of the contactless drive is a solenoid with a core that is free to move within the solenoid.

The solenoid and the core function to convert electric energy to mechanical power. The core functions as a hammer making 160 to 180 impacts per minute. The type BII contactless drives available for use are of the following type varieties: BII-400 with a core stroke of 400 mm and motor output of 0.8 kW that is capable of driving in angle steel electrodes measuring $50 \times 50 \times 5$ mm within 2 or 4 min in warm seasons and within 8 to 10 min in cold seasons; BII-500 with a core stroke of 500 mm and motor output of 1 kW capable of driving in angle steel electrodes measuring $50 \times 50 \times 5$ mm within 1.5 to 3 min in warm seasons and within 5 to 7 min in cold seasons.

If power-operated tools are not available and a small number of round stakes or angle steel electrodes are to be installed, they can be driven in with the aid of a hammer. In order to prevent flattening of the electrode top by the hammer, it shall be hammered through a steel plate and its lower end shall be pointed. The electrodes shall be driven into the trenches so that their top projects 150 to 200 mm

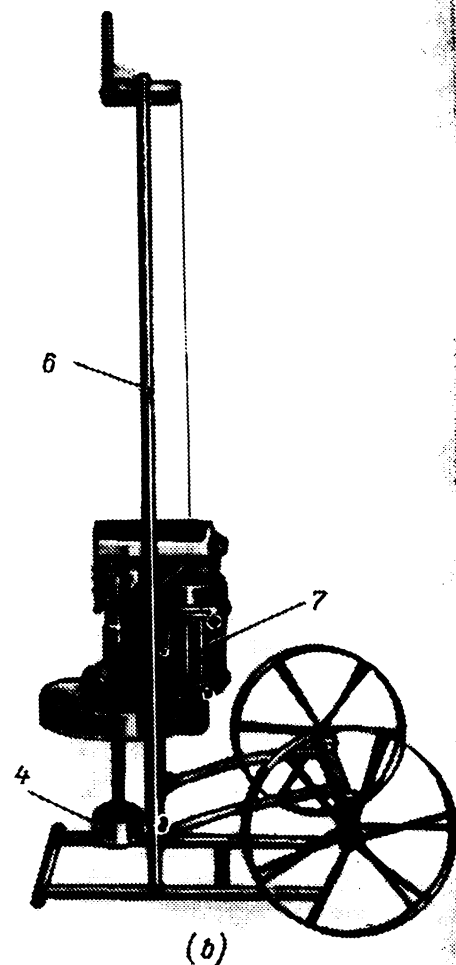


Fig. 174b. Driving an earthing stake by 39-1 earthing bore
6 — rod; 7 — motor

above the trench bottom for the connection of a steel strip. The steel connecting strip can be made of round rolled wire, at least 6 mm in diameter, or a rectangular steel strip, at least 4 mm thick and 48 mm² in sectional area. The connecting strip or the earthing main is connected to the earthing device electrodes at a distance of 50 or 60 mm from the upper edge of the electrode.

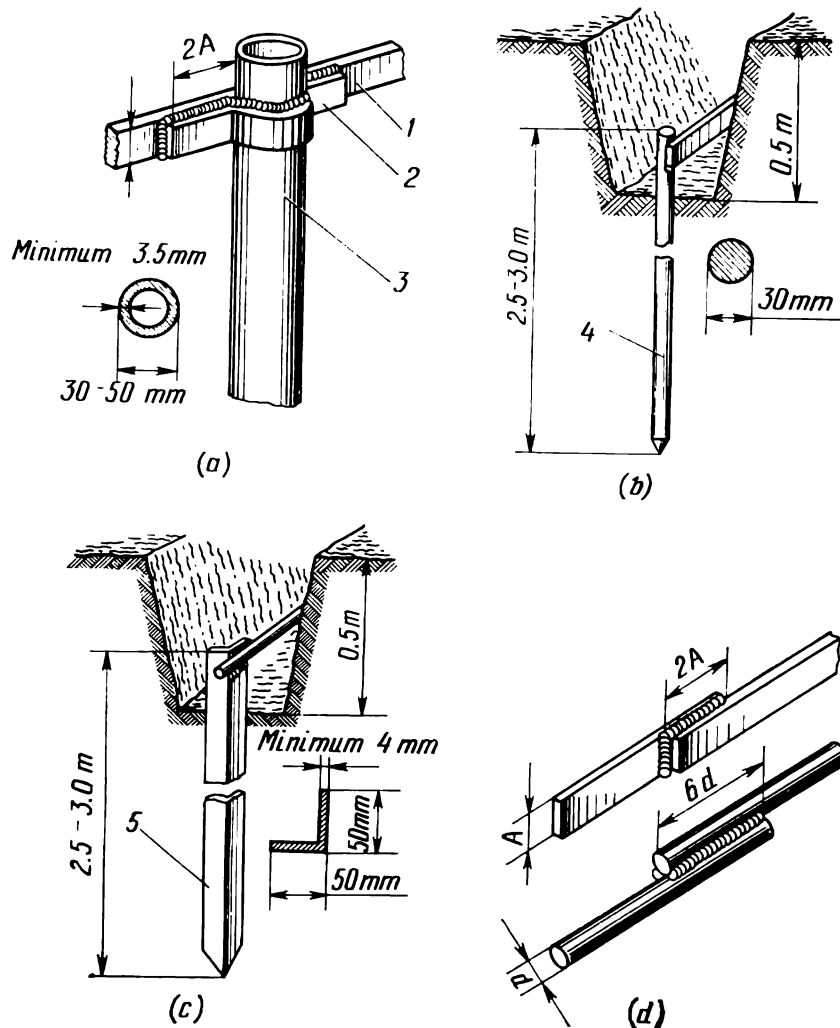


Fig. 175. Welding of earthing system connecting strips: a—to vertical tubular earthing device; b—to vertical round steel earthing device; c—to vertical angle plate earthing device; d—round-to-round and flat-to-flat strips; 1—connecting strip; 2—strap; 3—pipe electrode; 4—steel stake electrode; 5—steel angle plate electrode

The earthing main is connected to the earthing device electrodes at a distance of 50 or 60 mm from the upper edge of the electrode.

The earthing main shall be connected to the natural or artificial earthing devices, and the connecting strips to the earthing pipes or stakes by welding (Fig. 175a, b, c). The connecting strips and the earthing main are lap welded on a length of at least double the strip width in the case of flat strips or at least six diameters of round wires (Fig. 175d). The welding seam is applied in two layers on all the sides of the joint. The welded joint is checked for mechanical strength by hitting it several times with a hammer weighing 1.5 to 2 kg.

The earthing main entry into a building shall be marked with an identification sign in the form of letter 3 placed inside a circle, 20 cm in diameter, applied to the wall at a height of 150 to 180 cm in durable

paint. In the case of an open entry of the earthing main, the earthing conductors must be laid in steel conduits to avoid mechanical damage to them.

After the earthing device electrodes and earth conductors have been buried in the earth, appropriate reports on concealed work must be drawn up.

The points of installation of earthing electrodes and the route of the buried earth conductors shall be plotted on the plan, with distances from the electrodes and conductors to permanent landmarks being indicated.

10.3. Electrical Equipment Earthing Specifications

Electrical devices and structures must be reliably connected to the earthing main or directly to an earthing device by methods specified in Table 46.

For the connection to an earthing bolt on the device case or on a metal structure, drill a hole of a diameter 1 mm larger than that of the bolt on the end of a rectangular-section conductor or weld up a flat bus with an appropriate hole to the end of a round-section conductor. Thoroughly clean off the surfaces to be bolted together and coat them with petroleum jelly to prevent corrosion that may impair the contact. Where bolted earthing joints are to be made in humid locations or on outdoor installations, coat the contacting surfaces with anticorrosion grease AMC-1.

Earth conductors are connected to metal surfaces by welding, and to the cases of devices or frames of machines by welding or by reliable bolted joints. If these joints are expected to suffer jolts or vibrations that may cause them to come loose, measures shall be taken to reinforce these joints by using lock-nuts, locking washers, etc.

Mobile electrical equipment shall be earthed through flexible conductors. Each element meant for earthing shall be connected to an earthing device or earthing main by means of a separate tapped-off conductor. A series connection of more than one element to an earth conductor must never be allowed. Single-phase power receivers shall be earthed through a separate (third) wire. The neutral (working) wire shall never be used for the purpose.

In the arrangement of earthing systems the following elements can be used as earth conductors: neutral wires of three-phase circuits; metal building components (trusses, columns) and industrial structures (frameworks of switchgear installations, crane tracks, etc.); steel conduits of wiring systems and aluminium sheaths of cables; stationary open metal pipes of all purposes with the exception of pipelines for combustible and explosive mixtures, sewerage and central heating pipelines. Whenever these conductors are used for earthing, they must be reliably connected to the earthing system or to the neutral conductor of the building where the equipment shall be earthed. These conductors or their parts may be used as the only earthing conductors on condition that they conform to the Regulations for Electrical Installations as far as their conductance is concerned.

Metal sheaths of tubular conductors, those of insulating tubes, and lead sheaths of branch-circuit lighting distribution mains conductors shall never be used as earth conductors. In premises where earthing is necessary these sheaths shall be earthed and reliably connected over the entire length; jointing sleeves and junction boxes shall be connected to metal sheaths by soldering or by means of bolted joints.

Steel earth conductors shall be laid openly, with the exception of neutral conductors and metal cable sheaths, concealed wiring conduits, buried metal structures, and earth conductors laid in pipes. The cross-sectional area of steel earth conductors shall not be less than that specified by Table 45.

Open earth conductors laid indoors shall be accessible for inspection. In dry premises free from chemically active gases and vapours earth conductors may be attached directly to walls. In humid and extra humid locations and in atmospheres

Table 46

Methods of Connection of Electrical Equipment to Earthing System

Equipment	Parts to be connected to earthing system	Method of connection to part being earthed
Support and bushing insulators, nonlinear-resistance arrester, fuse, etc.	Device flange or base-plate	<ol style="list-style-type: none"> 1. Connect earth conductor to device earthing bolt; in the absence of earthing bolt or in case of connection to nonconducting structures, connect it to device fastening bolt 2. When the device is mounted on a steel structure, weld the earthing conductor to the structure mounting the device flange; connect each supporting structure of device to earthing main via separate conductor
Potential transformer and its series resistor	Potential transformer tank, LV neutral, LV winding phase lead (if stipulated by the project)	<ol style="list-style-type: none"> 1. Connect earthing conductor to transformer earthing bolt 2. Connect LV neutral or phase lead to case with flexible copper conductor
Current transformer	Secondary winding and metal case	Connect secondary winding to earthing bolt on transformer case with a flexible copper conductor, the case being earthed in the same way as support insulators
High-voltage circuit breaker	Breaker tank, operating mechanism, bedframe of live-tank oil circuit breaker	Connect earth conductor to earthing bolt on the tank or bedframe of circuit breaker and to operating mechanism
Isolator	Isolator base (bedframe), operating mechanism bedplate, signalling contacts case	Weld earth conductor to isolator bedframe, connect it to the bolt on operating mechanism bedplate and to signalling contacts case
Cast-in-concrete reactor	Flanges of bottom support insulators (lower phase) and those of top support insulators (upper phase), if three phases of one reactor group are arranged horizontally, flanges of support insulators of each phase shall be earthed	Interconnect all support insulator flanges of each phase with a common bus and bolt or weld the latter to earthing main
Power transformer	Transformer tank, film cutout (at neutral or phase lead of winding of up to 1,000 V)	Connect earth conductor to earthing bolt on transformer tank
Steel doors and wire guards in chambers or cubicles	Door or guard steel mount	Weld earth conductor to the mount of each door and guard
Wooden barrier	Steel barrier holder	Connect earth conductor to fastening bolt or weld it to holder
Switchboard and control console relay board, ancillary panel-board	Frameworks of boards and consoles	Weld earth conductor to the framework of each separately mounted board and console minimum at two points

res saturated with chemically active agents the clearance between the walls and the earth conductors shall be at least 10 mm.

Earth conductors shall be protected against the effect of chemically active agents contained in surrounding atmospheres. To this end, they shall be double coated with chemical-resistant enamel paint.

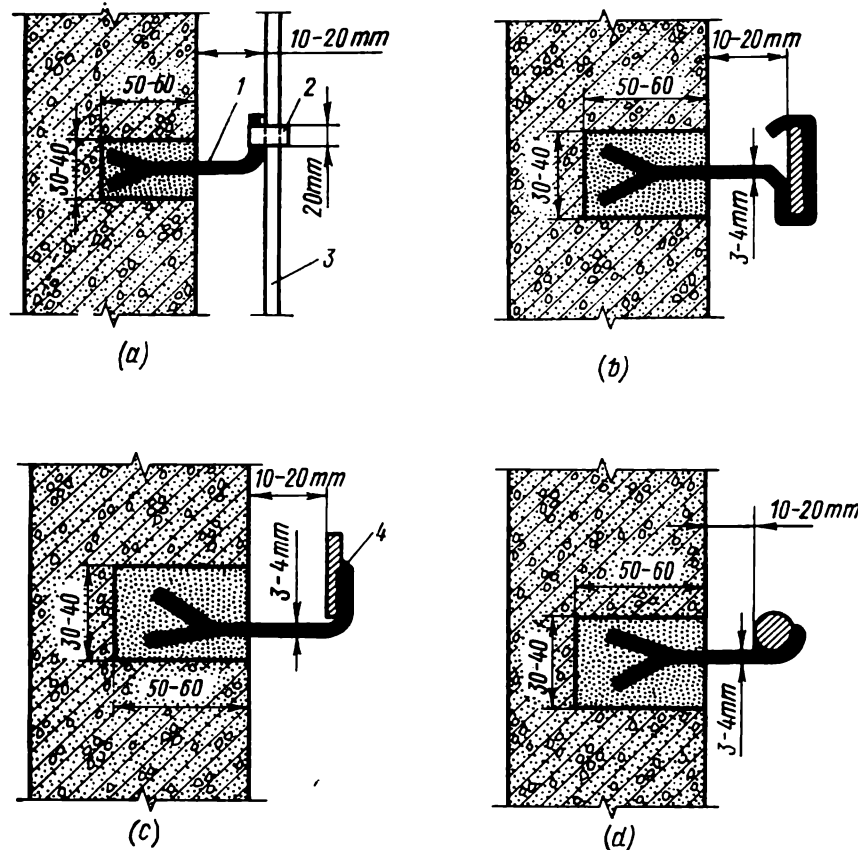


Fig. 176. Attachment of steel earth conductors to supporting structures
a—strip, by means of a holder; b—strip, by means of a clamping holder; c—strip, by welding; d—round bar, by welding; 1—rack; 2—holder; 3—earth conductor; 4—welded joint

Where earth conductors are crossing cables or various pipelines, and also where there is a danger of mechanical damage to them, they shall be laid in steel pipes or protected with angle steel plates.

Earth conductors are routed over walls in open grooves, in pipes, or in miscellaneous rigid framings.

Neutral conductors of wiring systems and overhead lines are connected by the same methods as phase conductors, that is, by soldering, welding, indentation, etc.

In humid locations and in atmospheres saturated with chemically active gases and vapours all connections shall be made by welding; if environmental conditions do not allow the use of welding bolted joints may be allowed; when this is the case, the contacting surfaces to be joined together shall be coated with anticorrosive compound.

When installing an earthing system, a reliable contact shall be ensured in all the joints and no open circuit shall be admitted over the entire length of the system.

Adjacent sections of metal structures shall be earthed by welding or by means of steel buses having a cross-sectional area of minimum 100 mm²; in electrical installations of up to 1,000 V with an earthed neutral these structures may be connected



Fig. 177. Electric hammer furnished with a vacuum cleaner for drilling holes to receive supporting structures of earthing buses

1—electric hammer C-494; 2—hose to vacuum cleaner; 3—vacuum cleaner

through conductors of the same cross-sectional area as those specified for earth conductors on the given section.

Where conductors are laid in steel conduits and these conduits are used as earth conductors, they must be reliably joined together and to the cases or frames of electrical equipment where they are brought in.

Earth conductors are connected to long earthing devices, such as pipelines, near their entries into the buildings by welding. If welding cannot be employed, connections can be made by clips run over with tin. The surfaces on the pipes to receive the clips must be cleaned off to metal lustre.

Points of connection of earth conductors and methods thereof shall be selected so as to ensure earthing circuit continuity and specified earthing resistance in all cases when pipelines are disconnected for repairs.

Water gauges and throttles shall have by-pass connections.

Earth conductors are routed over building elements on supporting

structures (Fig. 176a, b, c). Supporting structures mounted on straight sections are to be spaced 500 to 900 mm apart. Where earth conductors are laid in parallel to a floor, supporting structures shall be mounted at a height of 400 to 600 mm from the floor level. Where the route makes a turn, supporting structures shall be mounted at a distance of 100 mm from the turn angle on either side. Where earth conductors are brought in through floors or ceilings, they must be laid in steel pipes projecting by 30 to 40 mm on either side of the floor or ceiling.

At points of crossing expansion joints of buildings, earth conductors shall be looped in a lyre to function as an expansion device. Expansion devices can also be made of a steel cable, dia 12 to 15 mm. The flexible connection made of such a cable shall be looped to form a lyre, and its end shall be welded to the earth conductor on both ends of the expansion joint of the building. Where the flexible connecting cable crosses the expansion joint of the building, it shall be cut and its two ends shall be set 8 to 10 mm apart.

Installation of earthing systems involves such operations as drilling holes and making manholes in building elements. These operations must never be carried out manually by means of drifts, chisels, scarping tools, sledge hammers to avoid cracks on building components that may reduce their mechanical strength. Motor-driven tools shall be used for the purpose.

For drilling holes of up to 60 mm in diameter and up to 70 mm in depth, use can be made of a power-operated drift composed of a hollow rod with a shank and a drift bit. The bit is a changeable element that is screwed onto the rod. The rod is joined with the spindle of the electric drive (electric drill И-28, И-29, and the like) via a cone-terminated intermediate shank.

The type C-494 lifting and revolving electric hammer furnished with a BK9 or BK15 hard alloy-clad drift and a vacuum cleaner functioning to evacuate the grit (Fig. 177) can be employed to drill holes and recesses (up to 30 mm in diameter and up to 300 mm in depth in concrete walls.

In routing earth conductors, power-operated tools shall also be used for bus bending. Rectangular steel buses can be bent by means of a bending machine, [such as the type VIII TM-2 multipurpose bus-and-pipe bending machine that can bend buses measuring up to 100×10 mm. For bending pipes, it will be only required to re-arrange the rollers and to change the bending quadrant.

Flat and round earth conductors are connected and tapped off by welding (Fig. 178a, b, c, d). Open earth conductors are to be painted black. Arbitrary colouring is also allowed by Regulations for Electrical Installations (for example, to match the walls or panels), but in this case minimum two identifying black strips, 10 mm wide, spaced 150 mm apart shall be applied at the joints and tee-offs.

Earthing systems shall be checked when commissioned, and periodically in the course of operation.

Regulations for Electrical Installations specify the following checks for newly installed earthing systems:

(a) buried elements of earthing systems are checked for condition at random by unearthing; other elements are examined at accessible places;

(b) circuit continuity is checked between earthing devices and earthed elements. Open circuit and poor contact shall not be admitted;

(c) film cutouts mounted on electrical installations rated up to 1,000 V shall be checked for condition. These cutouts shall not be faulty and their rated voltage must correspond to that of the electrical installation;

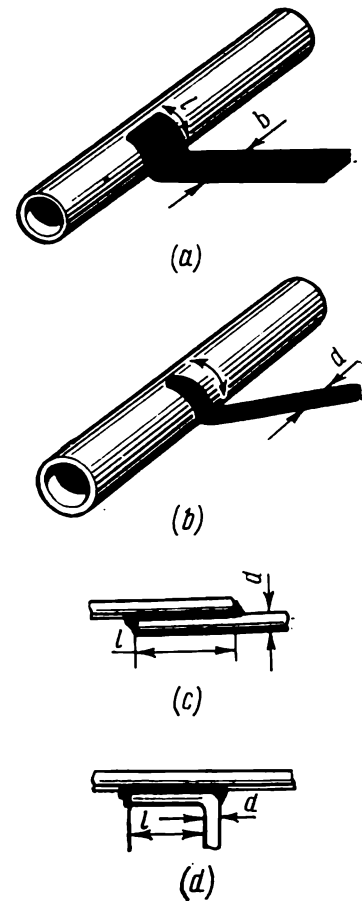


Fig. 178. Connection and tapping-off of steel earth conductors

a—connection of rectangular conductor to a pipeline ($l = b$); b—connection of a round conductor to a pipeline ($l = 8d$); c—interconnection of two round conductors ($l = 6d$); d—connection and tapping-off of round conductors ($l = 6d$)

(d) the phase-neutral loop impedance is checked on electrical installations with a solidly earthed neutral rated up to 1,000 V. The impedance must be of such a value that a phase-to-earth fault should cause a short-circuit current corresponding to the specified short circuit-current ratio in respect to the rated current of a fuse link or a circuit breaker; this check must be carried out on most distant and most powerful receivers, but not less than 10 per cent of their total quantity must be subjected to this check;

(e) the earthing system resistance shall be checked for compliance with specified values;

(f) cross-sectional areas of earth conductors shall be checked for compliance with project specifications and the requirements of Regulations for Electrical Installations.

Review Questions

1. What is the protective earthing system and how does it function?
2. What is zero potential point?
3. What natural earthing devices do you know?
4. What parts of electrical equipment and installations must be earthed?
5. How are earthing devices installed?
6. What elements of electrical installations can be employed as earth conductors?
7. What is required to do with earth conductors crossing expansion joints of building elements?
8. What requirements must newly installed earthing systems meet?

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